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CROP PRODUCTION

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CROP PRODUCTION

PRINCIPLES AND PRACTICES

A Handbook of Information for the
Student of Agriculture

BY

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PREFACE

Crop Production represents the effort of the authors to bring together some of the more important data from that vast fund of information which has been accumulated during the last fifty years by scientific experimentalists in the agricultural experiment stations, the U. S. Department of Agriculture, and other research and educational agencies, and to make them available for *ready reference*—alike to the student in the classroom and the man on the farm.

These important results, of the greatest practical value in establishing principles and determining the best practices in crop production, have hitherto not been easily accessible in the solution of practical problems or the improvement of practices in crop production.

This work originally was designed and prepared to meet the need in Iowa State College where the problem method of teaching had been adopted in classes in Farm Crops. Assembling of the information presented has been in progress for a number of years and a preliminary printing was made available in the fall of 1925. As presented here, that preliminary output has been carefully revised and enlarged, making it equally well adapted for the use of the student of crop problems in any section of the United States. To accomplish this, reference to particular studies of necessity has been confined to bare—but it is hoped, essential—details. Care has been exercised, however, to give the student the benefit of reference to the original sources of material in order that where such are available and conditions warrant, the original publications may be consulted.

In contrast with the usual text method of presenting the conclusions of the author with little or no information as to the extent or character of the investigations upon which they are based, it is the purpose here to present actual findings, or data—from which the student may make his own deductions and formulate his own conclusions. When used in the classroom it will devolve upon the instructor to aid the student to reach such conclusions as the facts justify.

It has been the purpose of the authors to make these results available without bias. In no case have data been selected with the idea of refuting, or proving, a particular theory or opinion. An effort has been made to include the essence of some of the more important contributions. In some cases, valuable data bearing on the subjects included may have been overlooked and it will be the aim of the authors to include in later editions such of these as come to their attention.

Circumstances have been such that the authors have had available to them the results of practically all important scientific research, both in this country and abroad. In addition, they have some familiarity with the crop production problems and practices in widely different sections and have tried to relate the scientific information available to their solution or improvement.

The senior author, who was reared on an Illinois farm, later had opportunity to study crop practices in the far South. His college work at the University of Illinois was supplemented by graduate work at the University of Missouri. After three years on the instructional and investigational staffs at the latter institution, he was called to the Iowa State College where for the past twenty years he has had charge of the instructional work in farm crops in the college and the investigational work with crops in the experiment station.

The junior author, who spent his early years on a farm in Kansas, came to maturity on an Oklahoma farm. He had his college training at the Oklahoma State College and after serving as a county agricultural agent in that state, pursued graduate study at the Iowa State College, where, for the past seven years, he has served on the Farm Crops instructional staff, giving particular attention to methods of teaching.

During the time the authors have been interested in teaching, different methods of instruction have been used with varying degrees of success. The problem method, as it has been employed for a number of years in the teaching of farm crops at the Iowa State College, has proven far superior to other methods. In adopting this teaching method, the greatest handicap encountered was in securing suitable texts and reference material. The use of texts which do not include comprehensive data practically precludes the possibility of using the problem method of instruction, and reduces the classroom work to a fact-cramming process, with little thinking or reasoning on the part of the student. The very satisfactory results secured in the use of the problem method of teaching farm crops at Iowa State College are largely dependent upon the accessibility of data which such a reference as *Crop Production* makes possible.

The teaching principle underlying the problem method consists in making available to the student known facts concerning the problem in which his interest has been aroused and encouraging his own solution thereof,—a method we believe fundamentally sound.

What more fact-fixing than aroused interest, plus available information, plus the personal solution upon established basic facts?

While primarily prepared for the use of college students, it is the belief of the authors that there is a demand for such material as is presented here on the part of all students of agriculture in whatever field their interests may center and that a handbook of such character as *Crop Production* will prove equally as valuable to the mature student—the practical producer of crops, agricultural writers and others, —as to students in schools and colleges.

The authors are indebted to Professor M. F. Miller, University of Missouri, for his critical reading of Chapters VII and VIII; to Dr. John E. Weaver of the University of Nebraska for his critical reading of Chapter V; to Dr. Ralph T. Stewart, Texas A. and M. College, for his critical reading of Chapter XV; to Dr. W. E. Loomis, Iowa State College, for his critical reading of Chapter IV, and to the agronomists in the different states for furnishing us information requested from time to time.

They are also indebted to Dr. W. H. Stevenson, head of the department of Farm Crops and Soils at Iowa State College, for reading a considerable part of the manuscript and for helpful suggestions and criticisms; to Professor William H. Lancelot, head of the department of Vocational Education, for material encouragement and for suggestions and criticism of the questions and application assignments which accompany each chapter; to Dr. I. E. Melhus, Professor of Plant Pathology; Dr. John N. Martin, Professor of Plant Morphology and Cytology; Dr. A. J. Drake, Professor of Zoölogy and Entomology; and to Dr. C. H. Richardson, Assistant Chief in Entomology, for the reading of parts of the manuscript and for helpful criticisms.

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To Kenneth Kopf the authors are indebted for his critical and painstaking work in checking all of the references; to Kirk Fox, editor of *Successful Farming*, and Henry A. Wallace, editor of *Wallace's Farmer*, for numerous illustrations; and to Lulu Lego Hughes and Helen Norene Henson for invaluable assistance throughout the progress of the endeavor.

H. D. H.
E. R. H.

Ames, Iowa
August, 1930

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CROP PRODUCTION

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CHAPTER I

WORLD DISTRIBUTION OF CROPS

From earliest colonial days until 1898, when the normal peak of crop exportation was reached, an ever-increasing volume of food products was exported from the United States. Though this country still ranks as one of the chief food exporting countries, it must be noted that the volume of crop products shipped to foreign countries is rapidly diminishing and food importations steadily increasing. For the year ending June 30, 1926, the aggregate of foodstuffs imported exceeded those exported.[1]

1. Crop Distribution and the World's Food Supply. In the past we have depended largely upon the surplus of the newer agricultural sections to supply the demand of the more populous territory but with the growth of population we must reckon with a more intricate economic situation. History records many famines due to crop failure. The memory of the tragic death from starvation of millions in China and Russia is still fresh in the minds of this generation. Not always has divine guidance and protection directed nor enabled a Joseph to hoard sufficient reserve for the "lean" years which were to follow. But the fact remains that heretofore a surplus has always existed; the problem of distribution has been the important factor. Difficulties in merchandising and transportation alone have prevented adequate relief.

Today the student of agriculture faces an increasingly complex problem. For him the study of crop production and distribution is of necessity associated with that of economics, for with increased population comes increased pressure on means of subsistence. The present annual increase in population in the United States[2] is approximately 1,500,000 as compared with 20,000,000 for the world. Nor is it unreasonable to anticipate a time when the food situation in our own country might become critical as has already been the case in the densely populated countries of the Orient.

2. Factors Which Influence World Food Supply. Every student of agriculture should be familiar with the general factors which at present influence the food supply of the world and should have a fair understanding of possible future developments. He should know something of (1) early theories concerning the food supply; (2) the present attitude toward the food supply of the future; (3) the extent of land suitable for crops; (4) the intensity of culture; (5) the crop production centers of the world, and (6) the factors responsible in limiting the extent of our crop areas.

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[1] Arner, G. B. L.—"Foreign Trade Index Number for Food Stuffs." *U. S. Dept. Agr. Yearbook* 1926, p. 386.

[2] Gray, L. C., *et al.*—"Utilization of Our Land for Crops, Pasture and Forests." *U. S. Dept. Agr. Yearbook* 1923, p. 451.

EARLY THEORIES CONCERNING THE FOOD SUPPLY

3. Population and Food Supply. A consideration of the problem of supplying sufficient food for the ever-increasing population of a world of limited acres has not been confined to the present generation. More than a full century ago it was discussed in printed form by Malthus,[3] an English nobleman, who presented the subject from the standpoint of limited acreage versus unlimited potential population. Malthus pointed out that the population of a country could increase in a geometrical ratio, while the food supply could increase only in an arithmetical ratio; that is, while each unit of increase in population might again increase, there was not the same elasticity in unit of increase in food per acre. For example, unless checked, the population of the United States might double every twenty-five years for an indefinite period. On the other hand, the yields per acre of a unit of land might be doubled once, twice, or even three times, but that there is a limit beyond which increase is impossible.

According to this authority, the basic check on population increase is the maximum limit of food supply. Famine, wars and pestilence serve to eliminate over-population, and there are other checks which precede the famine stage. For instance, because of the low wage level and the scarcity of food, marriage is not so freely contracted nor undertaken at so early an age as under more favorable living conditions. The suggestion of Malthus that the population of the United States might continue to double every twenty-five-year period proved to be an accurate prediction until about 1900, when the increase fell far below that number.

4. Soil Fertility and the World's Food Supply. Liebig,[4] a German, suggested the depletion of soil fertility as a limit to possible food production. He asserts that as, year after year, crops are produced and sold from the land, eventually the supply of plant food in the soil is exhausted and crops can no longer be grown.

In support of this theory the relatively non-productive soils in

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[3] Malthus, Rev. T. R.—*Essay on the Principle of Population.* London. Oxford University Press. 1798. Reprinted by Macmillan and Co., Ltd., p. 18. 1926.

[4] Liebig, Justus.—*Principles of Agricultural Chemistry.* English Edition. Walton & Maberly, pp. 43-48. 1855.

Mesopotamia, Persia, Egypt, Greece, Spain, and Italy have been cited, all of which were once very fertile. In the eastern and southern sections of our own country, large areas of once productive farm land are now abandoned because of low fertility.

Having become alarmed over the matter of depleted soil fertility, in 1898 the noted English scientist Sir William Crookes [5] sounded a vigorous protest, characterizing the custom of devitalizing the soil without replacing the necessary elements of plant food as fraught with "deadly peril," not only to England but to all civilized nations.

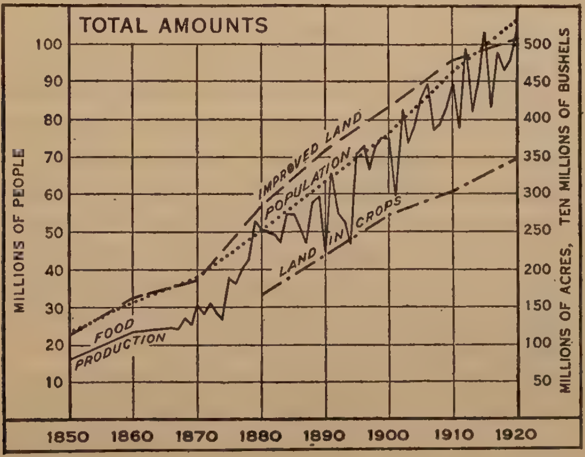

FIG. 1.—Relation of improved land, land in crops, and food production to population of the United States, 1850 to 1920. (U. S. Dept. Agr. Yearbook 1921, page 431.)

THE PRESENT ATTITUDE TOWARD THE FOOD SUPPLY OF THE FUTURE

5. The Attitude of the American Producer. While American agronomists generally share the concern of the scientists abroad, the American public, including the American farmer, with its present vivid conception of the producing power of American soil, regards as visionary any suggestion of a possible food shortage in the United States in the near future. The attitude of the average farmer in America toward the question of soil fertility and its maintenance is not materially different from that of his English neighbor. While our experiment stations have determined upon methods of maintaining soil fertility, comparatively few of those who are producing crops will make any particular effort to conserve the natural fertility or replace the plant food elements until materially reduced yields make conservation necessary. Then usually only such methods will be employed as give promise of immediate returns.

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[5] Crookes, Sir William—"The Wheat Problem." *Brit. Assoc. Adv. Sci. Rpt. 68*, pp. 8-9. 1898.

6. Production and Post-War Depression. While recognizing the fact that the surplusage of certain of our crop products resulted in a deplorable economic depression following the World War, the student of agriculture will be impressed with the findings of the United States Department[6] with reference to this particular matter and the suggestion that certain facts tended to hide the real situation with reference to crop production during this period. Four of these facts are as follows:

a. Regardless of the high prices paid for crop products during the war period, there was no great expansion of farming into *new* areas. There was, it is true, an expansion of acreage, but the exportable surplus was produced on land ordinarily devoted to domestic purposes; that is, pasture land was utilized for growing crops, especially wheat. The acreage used for growing feed for livestock was approximately twenty-two million acres less than that so utilized from 1909 to 1913, while the acreage devoted to cereals was increased by practically the same amount.

b. The crop acreage *per capita* was actually reduced during the decade 1912 to 1922.

c. There was no important increase in the average yield per acre during the period.

d. The consumption of bread cereals in Great Britain, France, Germany and Italy was approximately 80 per cent that of the years preceding the war.

7. The "Back to the Farm" Agitation. In discussing the attitude of the present generation toward the food supply of the future, we must not overlook the annual migration cityward of many farm boys and girls. It has been stated that there is grave danger, not to agriculture alone, but to our entire economic structure, in encouraging the most efficient and best trained boys to abandon the life of the farm for other lines of activity. This is no new lament. Nearly three-quarters of a century ago, when the great West was as yet scarcely touched, the United States Commissioner of Agriculture made the following statement in his report for the year 1862, "It is not only a mistake but a great misfortune that young men should feel dissatisfied with the comparatively slow gains of agriculture or that they should regard the farmer's life as one of tameness or drudgery."

Agricultural colleges have been severely criticized because many of their graduates enter other lines of activity instead of returning to the farm, and it is a pertinent subject for our consideration. In reply, it has been suggested that to indiscriminately encourage the "back to the farm" movement or to make wholesale criticism of the vocational adjustments of agricultural college graduates is to lose sight of the interests of the individual. If young men and women are to devote themselves to the cause of feeding the world, the living conditions on farms must be as favorable and the prospect of reasonable financial reward as great as are now available to persons engaged in other activities.

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[6] Gray, L. C., Baker, O. E., *et al.*—"Utilization of Our Lands for Crops, Pasture and Forests." *U. S. Dept. Agr. Yearbook* 1923, p. 415.

8. Rural and Urban Population. It has also been stated that with our increasingly efficient methods of production, agriculture can prosper only as more and more people make their homes in the city. The swing of population from country to city during the past one-hundred-year period is indicated by the figures on per cent of population classed as rural.[7] By ten-year periods these are for 1880, 70.5; 1890, 63.9; 1900, 60.0; 1910, 54.2; 1920, 48.6. This classification includes as "rural" all persons on farms and in places of less than 2500. Considering only the actual farm population there was a net decrease during the five-year period 1920 to 1925 from 29.9 to 25.2. During this five-year period the total population increased 16.4 per cent while the farm population decreased 8.2 per cent.

The large gross movement from farms to cities, which has been at or slightly above the 2,000,000-mark a year since January, 1922,[8] apparently still overbalances the gross movement from cities to farms, even with the increase on farms by births over deaths included. The net loss in total farm population has approached a half million per year since 1921, being the heaviest for the year 1926, when the decrease in the total farm population amounted to 649,000.[9]

9. Changes in Consumption with Increased Population. The consumption of certain types of food varies with different countries. It has been estimated by Gray *et al.*[10] that if we in America should adopt the German standard of consumption for animal products, 27,000,000 acres of grain crops and potatoes would be necessary and a net saving of 37,000,000 crop acres would result. In comparing the consumption of important food products in Germany and the United States, if we consider the per capita consumption in the United States as 100, the percentages of the various commodities used in Germany per capita are as follows: beef and veal, 57.6; pork and pork products, including lard, 90; mutton and lamb, 37.5; poultry, 23.9; eggs, 56.5; milk, 67.6; butter, 101.4; cheese, 300.9; fish, 115.1; wheat flour, 63.5; rye flour, 3,670.2; rice, 133.3; other cereals, 350.2; potatoes, 271.3; sugar, 46.6.

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[7] *U. S. Dept. Agr. Yearbook* 1926, p. 1235.

[8] Galpin, C. J.—"Population Flow from Farms to Cities Declines." *U. S. Dept. Agr. Yearbook* 1926, p. 592.

[9] Editorial—"Farm Population Shows Big Decrease." *Rural America*, Vol. 5, No. 6 (June, 1927), p. 11.

[10] Gray, L. C., *et al.*—"The Utilization of Our Lands for Crops, Pasture and Forests." *U. S. Dept. Agr. Yearbook* 1923, p. 415.

In summarizing the probable changes in consumption in the next few decades, Gray *et al.* predict an increase in the per capita consumption of potatoes and cereals, little change in the consumption of pork and pork products, but a reduction of 20 per cent in beef products. On the basis of these assumptions and of an increase in the productiveness of crop land, as well as in the carrying capacity of pastures, this country would require for our probable population of 150,000,000, three or four decades hence, about 373,000,000 acres of crop land and 222,000,000 acres of pasture other than woodland, or an additional 40,000,000 acres in crops and improved pasture over our present acreage.

THE EXTENT OF LAND SUITABLE FOR CROPS

10. Marginal Land. In a consideration of the outlook for the future food supply of the world, the importance of the number of available tillable acres may be easily overemphasized. It is still possible for a young man to "homestead" a piece of land much as his father was enabled to do before him. But few young men are doing this. The reason lies in the quality of land available for crop-growing purposes. The land now available is largely *"marginal land"*; that is, land on which the yielding power, location or difficulty of bringing it into a state of productivity, makes the cost of production so high as to render the farming of such land profitable only when prices are high. Land requiring large expenditures for irrigation, clearing or drainage, and dry farming regions in the West are examples of such *"marginal land."*

A more or less comprehensive understanding of the world situation with reference to the present and possible future use of land for producing food may be obtained from a study of the data presented in Table 11.

THE INTENSITY OF CULTURE

12. Crops Grown and Intensity of Culture. The intensity of culture of land may be partly measured by the purpose for which it is used. The methods based primarily on the utilization of the natural growth of herbage either for grazing or lumbering, are perhaps the least intensive of all. As a country becomes more densely settled, the natural growths are practically destroyed and the land is utilized for cultivated crops. Therefore, in many of the older and more densely populated countries, large numbers of cattle and hogs, throughout

11. Total Area of Different Countries, Per Cent of Land Arable, Per Cent of Arable Land in Cereals, Cropped Land Per Capita and Acre Yields, 1921-25.[11]

COUNTRY	TOTAL AREA MILLIONS OF ACRES	PER CENT OF LAND ARABLE	PER CENT OF ARABLE LAND IN CEREALS	ACRES OF CROPS PER CAPITA	WHEAT BU. PER ACRE	CORN BU. PER ACRE	POTATOES BU. PER ACRE
Canada	2,338	2.90	63.4	7.26	16.4	44.3	157.1
United States ...	1,902	17.1	64.5	2.89	13.8	27.7	106.9
Argentina	690	7.6	52.6	5.22	12.0	25.2	90.2
Brazil	2,102	0.6	75.7	0.41	15.0	25.1	94.9
Chile	186	2.7	36.8	1.28	17.8	24.8	144.1
Austria	21	22.6	58.1	0.71	18.4	25.4	138.9
Great Britian	57	23.9	44.0	0.31	35.3	...	217.0
Czechoslovakia ..	35	42.1	53.8	1.02	23.6	26.8	151.5
France	134	42.1	49.9	1.42	21.5	17.8	125.1
Germany	117	43.4	56.6	0.79	27.3	...	187.6
Hungary	23	59.1	71.2	1.62	17.8	23.9	89.0
Italy	77	42.7	54.3	0.80	17.1	24.9	78.4
Norway	77	2.1	26.7	0.59	23.6	...	229.7
Poland	93	48.6	56.7	1.54	17.5	18.6	177.7
Russia (European)	1,037	19.2 [d]	...	2.4 [d]	9.2	21.3	128.3
Spain	125	31.7	48.3	1.82	13.6	22.2	125.6 [a]
Sweden	101	9.3	43.6	1.55	30.4	...	169.5
China	2,737	9.3 [e]	...	0.50 [e]	...	...	....
India (British) ..	664	46.0	50.7	1.23	11.4	14.0	....
India (States) ...	133	60.1	45.2	1.11	...	...	....
Japan	96	15.5	83.7	0.25	23.6	25.4	140.7
Russia (Asiatic) .	4,201	.8 [d]	...	0.89 [d]	10.6	21.3	102.1
Australia	1,903	1.2	50.0	3.73	12.8	26.9	99.7
New Zealand	66	2.9	18.1	1.38	29.6	50.0	212.5
Egypt	247	3.4	49.5	0.60	25.3	34.8	....
Union of S. Africa	302	2.2	85.3	0.89	8.2	11.5 [b]	44.6 [c]

[a] Four-year average. [b] Two-year average. [c] Three-year average.
[d] *U. S. Dept. Agr. Yearbook* 1920 (Calculated).
[e] Based on estimate of 400,000 sq. miles in arable land.

their entire existence, are fed harvested crops in small enclosures or in stalls in the barn.

After grazing or lumbering, general farming is the next in degree of intensity. The elimination of a considerable part of the pasture areas from this type of farming brings large acreages of cereals and other cash crops. Given a considerable proportion of non-tillable land in a heavily populated section, the trend is toward dairying in order that such land can be best utilized for pasture.

The production of truck crops represents a still more intensive system of farming. The tendency is to produce those crops giving the greatest cash return per acre.

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[11] *U. S. Dept. Agr. Yearbook* 1925 for crop yields. *International Yearbook of Agricultural Statistics* 1925-26 for area, population, arable land, land in cereals, and acres of crops per capita except as noted.

13. Use of Fertilizers and Intensity of Culture. The kind and amount of manure and commercial fertilizer used are indicative of the intensity of production. In most European countries, the manure from animals is very carefully collected, stored and applied to the land. In certain sections of Asia all sewage and human waste is so utilized. In parts of the United States various commercial fertilizers are liberally and regularly used to increase the acre yield and the profit per acre, while in other sections and with other crops commercial fertilizers are seldom used.

14. Price Levels and Intensity of Culture. The attention given conservation of soil fertility and production practices which will net maximum returns per acre is dependent to a considerable degree on relative price levels. During the period 1840 to 1880 in England, the English farmer raised his yield of wheat from 11 to 30 bushels per acre by using labor freely and by the application of manure and commercial fertilizer. However, England's national policy during this period became less favorable to agriculture, as instanced by the passage in 1850 of the famous corn laws removing the tariff on wheat. A little later, our own great Middle West began to produce wheat extensively for export. While yields in this country were only about fourteen bushels per acre the quantity produced per man was so large that wheat could be shipped across the Atlantic and sold on the English market at a price considerably below the actual cost of producing wheat there. English farmers could not compete under these handicaps.

Germany's policy has been almost the reverse of England's. She adopted a favorable national policy toward agriculture with the view of making herself self-supporting in case of war.

15. Yield per Acre as Reflecting Intensity of Culture. The average yield per acre of certain crops in representative countries of the world, as presented in **11**, may give some indication of the demand for crop products in these countries, although perhaps the relative per capita acreage in such crops is a more accurate indicator. Any protection afforded agriculture in a given section by favorable rates of transportation, tariffs, etc., may greatly modify this relationship.

In the United States, the per capita acreage of farm land reached a maximum at the outbreak of the Civil War, when there were 13 acres per capita.[12] By 1870 this had dropped to 10½; 1880 to 10½; 1890 to 10; 1900 to 11; 1910 to 9½; and by 1920 to 9.

[12] Gray, L. C., *et al.*—"The Utilization of Our Lands for Crops, Pasture and Forests." *U. S. Dept. Agr. Yearbook* 1923, p. 433.

16. Trends in Acre Yields, U. S. Weitz[13] has shown the trend in yield per acre for corn, wheat, oats, and potatoes in the United States from 1885 to 1923. (17) In considering these yields it may be well to keep in mind the fact that a trend toward increased yields may reflect an expansion of acreage to more productive soils, the more liberal use of fertilizers, the use of better adapted varieties or improved cultural methods; while decreased yields may indicate an expansion onto less fertile, poorly adapted soils, decreasing fertility or less intensive methods of culture.

17. Corn, Wheat, Oats, and Potatoes: Five-Year Moving Average Yield per Acre, United States, 1885-1923.

Year	Bushels				Year	Bushels			
	Corn	Wheat	Oats	Potatoes		Corn	Wheat	Oats	Potatoes
1885	24.4	11.9	27.0	76.9	1905	28.0	14.0	29.9	96.3
1886	24.1	11.8	26.6	74.7	1906	28.1	14.2	29.2	96.5
1887	24.5	11.8	26.7	73.0	1907	27.9	14.9	28.9	95.8
1888	23.4	11.9	25.3	68.9	1908	27.6	14.7	28.4	97.1
1889	24.5	12.5	26.1	72.9	1909	26.2	14.1	27.1	92.8
1890	25.2	12.8	26.0	74.0	1910	26.7	14.4	29.8	96.4
1891	24.5	12.8	25.5	72.3	1911	26.0	14.7	30.6	97.2
1892	22.8	12.9	24.9	69.6	1912	25.9	14.8	30.5	97.8
1893	24.1	13.4	26.9	78.7	1913	26.0	15.4	31.7	98.3
1894	24.3	12.8	26.1	78.2	1914	26.1	15.4	32.8	98.2
1895	24.5	12.8	26.7	79.4	1915	25.6	15.0	32.7	95.7
1896	25.0	13.6	27.8	80.4	1916	25.7	15.1	33.8	96.8
1897	26.3	13.4	29.0	85.4	1917	26.4	14.3	33.7	92.9
1898	26.2	12.9	29.0	81.6	1918	27.0	13.7	33.2	95.7
1899	23.8	13.4	28.9	76.5	1919	28.1	13.8	31.9	98.0
1900	24.5	13.7	30.3	82.1	1920	28.5	13.7	30.5	98.9
1901	24.5	13.3	30.0	83.7	1921	29.5	13.3	30.0	101.5
1902	24.8	13.3	30.2	88.2	1922	28.3	14.0	31.2	108.7
1903	25.4	13.9	31.0	89.1	1923	27.7	13.9	30.9	107.4
1904	28.1	14.1	32.0	96.2					

18. Yield Trends by State Groups. The data presented under *18a* serves to indicate the trend in crop yields in various sections of the United States.

In both the spring wheat and the winter wheat regions of the West crop yields have remained rather stationary or have declined to a lower level, owing to the fact that extensive production methods still continue to be most profitable from an economic viewpoint and as a result of the expansion of the crop area onto drier lands of naturally lower yielding ability.

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[13] Weitz, B. O.—"The Trend toward a More Effective Use of the Land as Shown by the Yield per Acre of Certain Crops." *U. S. Dept. Agr., Dept. Bul. 1458*, 1926.

18a. Trend in composite yield per acre for corn, wheat, oats, and potatoes. (1885-1889 = 100)

YEARS	PER CENT			YEARS	PER CENT		
	Middle Atlantic States	East North Central States	Northern Section South Atlantic States		Middle Atlantic States	East North Central States	Northern Section South Atlantic States
1885-1889	100	100	100	1905-1909	127	124	146
1890-1894	100	96	107	1910-1914	138	126	159
1895-1899	120	112	125	1915-1919	136	131	170
1900-1904	114	116	126	1920-1924	145	125	177

19. Higher Prices and Greater Yields per Acre. It appears safe to predict that developments in the forthcoming decades, as in the past, will be dependent largely on the prices of agricultural products. Rising prices of food products would normally result in increasing intensification, and a higher level of soil productivity would follow the wider use of better cultivation methods, the development of suitable rotations including the growth of legumes, more efficient use of crop residues and animal manures, a greater use of commercial fertilizers, and the more common use of selected seed. A period of falling prices in agricultural products tends to arrest temporarily the advance toward higher standards of production, but the increasing demand of our steadily growing population for food must result ultimately in a level of prices that will justify the wider use of improved methods of production. Developments in other parts of the world will materially influence the time required to bring this about.

20. Labor per Acre and per Unit of Production. Gray, Baker, *et al.*[14] present figures showing the number of people engaged in agriculture and the number of horses used per one thousand acres of crop land. From these figures the approximate ratio of horses to men has been determined. These figures include persons in cities employed in the manufacture of machinery as well as those directly on the farm.

In America, there are approximately 2 horses or mules to 1 agricultural worker, while in England and Wales, Germany, Belgium, and France the average shows 2 workers to each horse or mule. For these four countries, the average production per acre, for seven important crops, is 41 per cent greater than for the same seven crops in the United States. Baker also states that, in general, after a certain average in productivity per acre is obtained, probably somewhat higher than that now prevailing in this country, a marked increase in

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[14] See reference 10.

20a. Number of agricultural workers and of horses per 1000 acres of crop land.

AREA	PERSONS	HORSES	NO. OF HORSES PER 100 MEN
Italy	237	42	18
Germany	160	70	44
France	130	55	42
England and Wales	106	125	118
Scotland	58	60	102
United States	40	80	200
So. Carolina	98	42	43
New York	40	62	155
Iowa	20	80	400
No. Dakota	12	45	375

the average production per acre is obtained only by a much greater expenditure of labor.

21. Size of Farm. By some, the size of the farm under one operator's management has been considered a measure of the efficiency or intensity of production. These believe that efficient management or efficient use of labor is impossible on small farms. A noted English agriculturist has given it as his opinion that England would do better agriculturally with larger farms. He suggests areas of from 2,000 to 3,000 acres each as desirable for that country. At present, 42 per cent of the improved land in England is in farms of from 100 to 300 acres each. In Germany, 28 per cent of the land is in farms of approximately 49 acres each. In France, the average area per farm is 32.2 acres, while in the United States it is 148.2 acres. In the plains area of Austria the average farm is around 250 acres, while the average areas of farm units in several other countries are approximately as follows: Denmark, 4 to 10 acres; Japan, 2.6 acres; China, approximately 2.0 acres. The general tendency is to expect larger returns per acre and smaller farms in the older sections of the world.

22. Size of Farm and Crops Grown. The nature of the crops grown upon the land together with the general type of farming, are the chief determiners of the size of the farm. It is reasonable that in the wheat regions of the world, "farms" should be more extensive in size than in regions practicing general farming. One man with a set of equipment can adequately care for a much larger acreage of wheat than of corn and many times the acreage of such crops as cotton, tobacco, or onions.

The average acreage per farm for the different groups of states as presented in Table *22a* is important for study in connection with the types of farming followed most generally in these regions and with the kinds of crops occupying the greater proportion of the land in these regions.

22a. Average size of farms and acreage of improved land per farm.[15]

Group	Average Acres per Farm	Average Acres of Improved Land per Farm	Total No. of Farms in Area
N. Atlantic (9 states)	99.0	56.2	581,711
S. Atlantic (9 states)	84.4	41.9	1,158,976
N. Central; east of Mississippi (5 states)	108.5	81.0	1,084,744
N. Central; west of Mississippi (7 states)	234.3	156.2	1,096,951
S. Central (5 states)	123.2	53.0	2,047,688
Far Western (11 states)	362.7	113.0	478,273
Entire United States	148.2	78.0	6,448,343

23. Trends in Size of Farm. Certain definite trends in the average size of farms in the different states and groups of states have been in progress during the past half century as is evident from the data presented under *23a* for a number of the corn belt states. Important differences in the average size of farms in different states, also in the direction of trends at different periods during the past seventy years, are indicated.

23a. Trend in size of farms in the corn belt; acres.

	Ohio	Illinois	Iowa	Kansas	Average Six Corn Belt States
1850	125.0	158.0	184.8	....	156.5.
1860	113.8	145.9	164.6	171.0	155.8
1870	110.8	127.6	133.6	148.0	129.8
1880	99.2	123.8	133.5	154.6	124.3
1890	92.9	126.7	151.0	181.3	130.7
1900	88.5	124.2	151.2	240.7	136.9
1910	88.6	129.1	156.3	244.0	140.3
1920	91.6	134.8	156.8	274.8	149.0
1925	91.0	136.0	156.0	264.0	148.3

Considerable has been said in recent years of the possibilities of large scale farming in the United States. This consists essentially of relatively large areas of land operated under the management of one person who employs such labor as is required. In connection with this method, large implements and power units are used to replace, wherever possible, the more expensive man labor. The purchase of supplies, selling, and the choice of crops grown, or enterprises taken up, are better judged, theoretically, by the competent manager than by the individual small acreage farmer. A number of such projects are in operation in the United States.

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[15] *U. S. Dept. Agr. Yearbook* 1922, p. 1008.

Opponents of this system suggest that this would reduce the farm worker to a state resembling peasantry, or that of a factory worker who mechanically did his work without interest in the successful outcome of the project.

Crop-Production Centers of the World

24. Native Vegetation and Crop Areas. Vegetative growth is nature's response to environmental conditions. The character of the vegetation is closely related to climatic conditions, particularly those of moisture and temperature. The maximum vegetation is found in extremely moist, hot, tropical regions. The jungle exemplifies one extreme of vegetation, the desert the other extreme. Between these lie the short grass sections, the tall grass or prairie grass sections, the open forest or open woodland, and the true forest. Our great crop producing areas may be judged somewhat by a comparison of Figure 2 with the world maps showing the distribution of production for individual crops.

25. World Crop Centers. Some of the more important crop-production centers of the world are as follows: (1) Central United States and Canada, (2) Northern Argentina and Southern Brazil, (3) areas in South Africa, (4) parts of Northern Africa, (5) Central and Western Europe, (6) India, (7) parts of Australia, and (8) parts of Asiatic Russia.

26. Central United States and Canada. The corn, cotton, and small grain belts of the United States combined with the grain belt of southern Canada make the greatest crop-production region in the world, and rank first in the production of corn, wheat, oats, hay, cotton, and tobacco, and second in the production of barley. It is also unusual in that, generally speaking, it is populated with people using a common language, having common standards and motivated by common ideals. Most lands of similar area are broken up into numerous nations, each with economic barriers and racial prejudices which tend to modify the cropping systems. In the United States, the crops, in order of their farm value are: corn, cotton, hay, wheat, oats, potatoes, tobacco, barley, sweet potatoes, grain sorghums, rye, sugar beets, rice, peanuts, beans, flax, sorghum for sirup, clover seed, buckwheat, broom corn. In Canada the largest acreage is devoted to wheat; followed in turn by oats, hay, barley, mixed grains, all corn, rye, flax seed, fodder corn, potatoes, buckwheat, corn for husking, root crops, peas, beans, sugar beets, and tobacco.

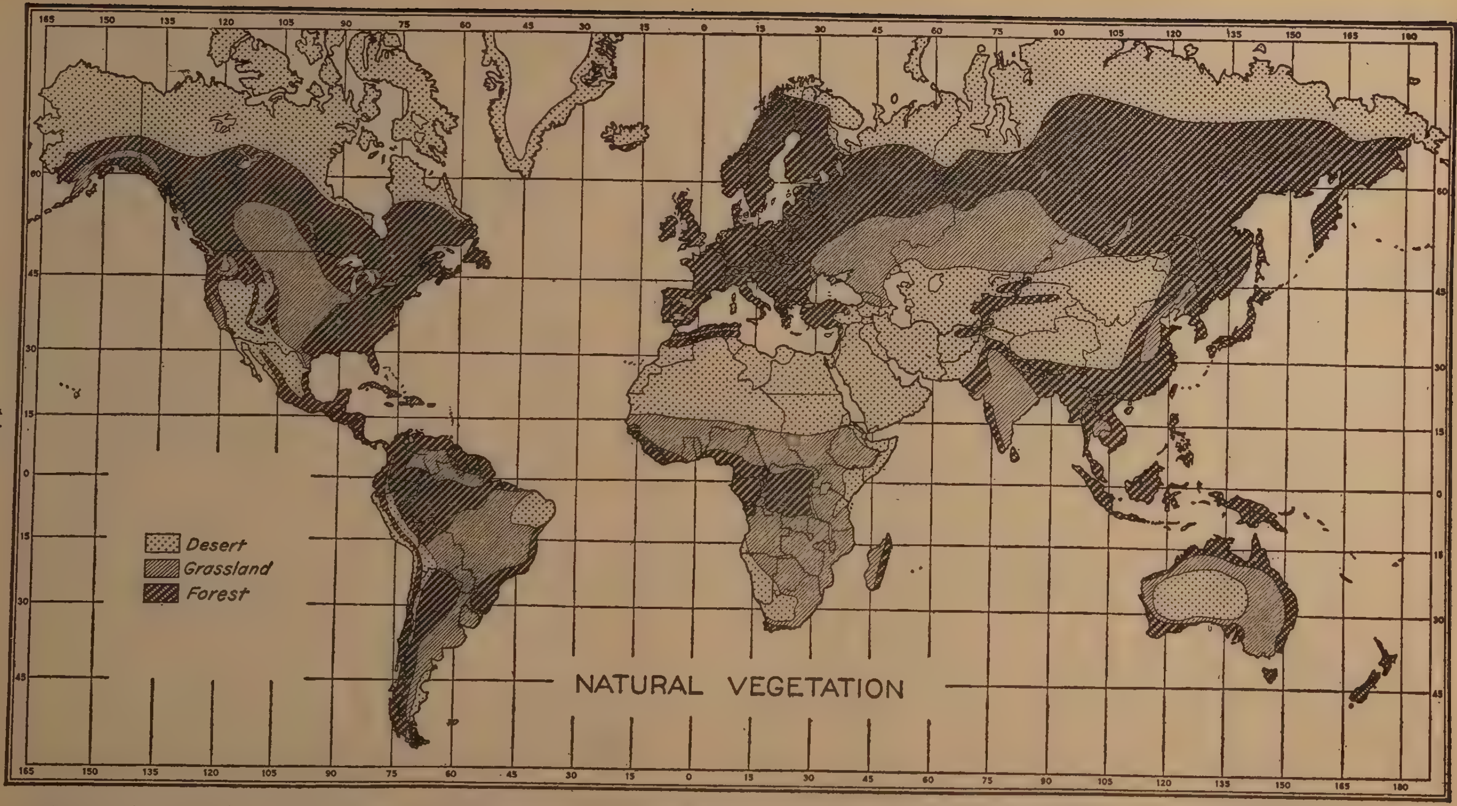
Desert
Grassland
Forest
NATURAL VEGETATION

FIG. 2.—A generalized map of the natural vegetation with three divisions: desert, grass land and forest. (U. S. Dept. Agr. Yearbook 1924, page 467.) *Is there any particular relation between the important crop areas of the world and the native vegetation of these areas?*

Based on the predominant crops this great area is divided roughly, from south to north, into the cotton belt, the corn belt (which may be subdivided into the corn-wheat and corn-oats belts) and the small grain belt; with, in the northeastern portion of the United States, a hay and forage section. In the hay and forage section is the heavy population incident to great industrial regions, conducive to dairying and trucking. Passing from this area, west, southwest or northwest, we find in turn, a general farming section, then the grain-growing regions, and finally, the pasturing or grazing areas.

27. Argentina and Southern Brazil. In Argentina the crop area is strictly limited by lack of rainfall, the entire area being less than one-fifth that of the United States. The bulk of the cropped land in Argentina corresponds more closely to the area of the Great Plains than to that of the corn belt. In the order of their importance the Argentinian crops in 1925 were: alfalfa, wheat, corn, flax, oats, barley, rye, potatoes, and sugar cane; while in Brazil the order was corn, cotton, rice, wheat, tobacco, and potatoes.

28. The Union of South Africa and the Bordering States. The total area of the cropped land in this territory is less than one-third the state of Iowa, and over four-fifths of it is devoted to the growing of cereals. In order of their importance, the principal crops are: corn, wheat, oats, grain sorghum, sugar cane, alfalfa, rye, barley, and millet.

This region is largely undeveloped, but it is believed to have great potential possibilities as a crop-producing region, and may eventually become an important factor in world markets.

29. Egypt, Algeria, and Morocco. The region of Northern Africa has about the same latitude as that of the southern part of the United States. Were it not for the fertile Nile valley and portions of Algeria and Morocco, crop production in this area would be of slight importance in world production. With approximately eight and one-third million acres of arable land, Egypt has four million acres in cereals. In order of acreage the crops are: corn, cotton, hay, wheat, beans, barley, rice, millet, lentils, and sugar cane. Algeria is of some agricultural importance and has approximately six million acres of arable land, the greater part of which is devoted to cereal crops. The principal crops are wheat and barley. Next in order are oats, beans, tobacco, edible roots and vegetables, potatoes, peas, sorghum, and millet. In the extent and variety of its crops, Morocco is practically identical with Algeria. As in Algeria the barley acreage exceeds that of wheat.

30. Central and Western Europe. The industrial centers of Europe are along the North Atlantic coast. In this industrial region is the dairy, hay, and root crop section of Europe. The hay and pasture region extends from the southern part of Norway and Sweden across European Russia. Just south of this area oats and flax are grown and still further to the south sugar beets, winter wheat, barley, and rye. To the west and south is the corn region of Europe, including northern Italy, Roumania, Hungary, and parts of adjoining countries. Taking Europe as a whole, the crops in order of their importance are hay, wheat, rye, oats, barley, corn, potatoes, sugar beets, flax, tobacco, rice, and hops.[16]

31. India. Although the total area of India is about one-third that of the United States, its crop area slightly exceeds that of our country. Because of the volume of cheap labor available, India depends on hand labor rather than upon horses and machinery. This hand labor, equipped with crude wooden plows and occasionally using oxen, prepares the seedbeds and cultivates the crops. Undoubtedly, the greatest acreage is devoted to rice, with the other crops in about the following order: sorghum, legumes and edible seeds, wheat, cotton, gram (pulse), millet, barley, corn, sesame, rape, mustard, flax, and sugar cane.

32. Australia. Australia and the United States have approximately the same total area, though in 1925 the area of land used for the production of harvested crops in Australia was less than one-fifteenth of that so used in the United States. This is due to the fact that but a narrow border of the Australian continent receives sufficient rainfall for agricultural purposes, and even within this belt, particularly in the east, is an area where the rainfall is scanty and cultivation is made possible only by alternating with fallow. Three-fourths of the crop area is devoted to wheat and to fallow in preparation for wheat. Other crops in order of acreage are oats, fodder crops, corn, barley, sugar cane, alfalfa, potatoes, cotton, peas, and minor crops.

33. Asiatic Russia. The area included in this section is almost three times that of the United States. With a total area of nearly five and one-fifth billion acres, less than 7 per cent of the land is in cultivated crops. The crop production of this great region apparently could be increased very materially. Outside of hay and forage (for which there are no statistics) the most important crop is wheat. The other crops in order of acreage are: oats, barley, potatoes, maize, flax, hemp, cotton, sugar beets, rice, spelt, grapes, and tobacco.

34. Other Important Areas. Comparatively little information is available concerning the crop production of parts of China and accurate statistics are not available even on the production of some of the better known portions. It is a well known fact that parts of this country offer great possibilities in the production of such crops as rice and sugar.

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[16] Jonasson, Olof—"Agricultural Regions of Europe." *Economic Geography.* Vol. 1, No. 3, 1925, p. 277.

35. World Crop Maps. A study of the world production of particular crops is most enlightening, not only from the standpoint of the adaptation of these particular crops to soil and climatic conditions, but also from the standpoint of world markets. World production maps for seven of the most important crops are presented herewith. Each map is a unit in itself in that it is not comparable to the others from the standpoint of volume of production. On one map a dot may represent 1,000,000 bushels, in another 1,000,000 pounds, and in still another 10,000 acres.

a. Wheat. Satisfactory production statistics are not available for some important producing countries. Before the World War Russia ranked first in the production of this crop, while the United States was second. It will be noted that the centers of production approximate 45° north and 30° south latitude.

b. Corn. Over three-fourths of the world's corn crop is produced in the United States, but the corn production of Argentina is relatively more important on the world's market because of the fact that approximately one-half of the Argentine crop is exported while only about one per cent of the crop of the United States is exported. Corn is an important crop in South Africa but yield statistics are not available. Corn is likewise important in Brazil, Mexico, India, and southern Europe.

c. Oats. It will be noted that oat producing areas correspond very closely to those of wheat and corn. Like wheat, most of the world's crop is produced in the north temperate zone.

d. Barley. Barley shows almost exactly the same distribution as wheat, corn, and oats.

e. Rice. Practically all of the rice of the world is grown in the tropical and subtropical countries of the Eastern hemisphere. Excluding China, on which statistics are not available, over half of the world's crop is produced in India. The rice crop is of great importance in Japan and Java and is becoming of greater importance in the United States.

f. Sugar. The world's sugar crop comes from cane grown in the tropical and subtropical zones and from sugar beets grown in the temperate latitudes as far north as Sweden. The most rapid expansion in the production of sugar in recent years has been in tropical countries and especially in Cuba. Cuba now produces over one-fifth of the world's supply.

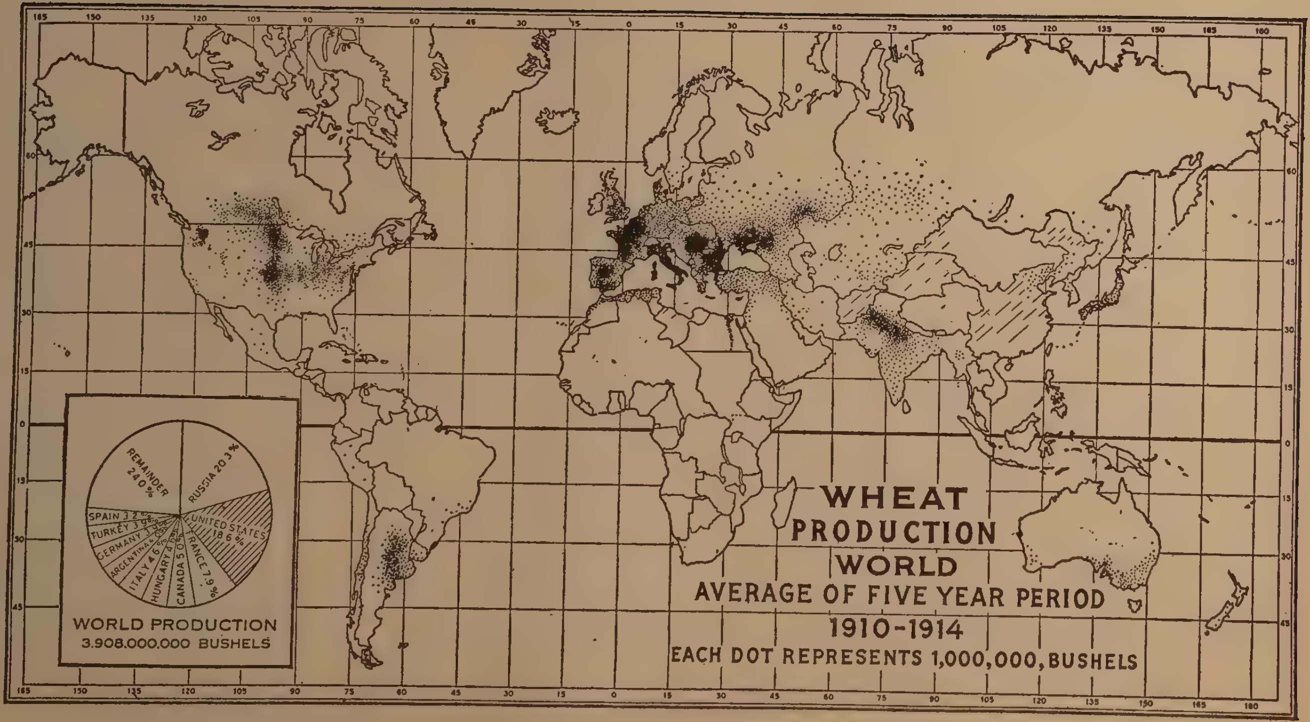

WHEAT
PRODUCTION
WORLD
AVERAGE OF FIVE YEAR PERIOD
1910-1914
EACH DOT REPRESENTS 1,000,000, BUSHELS
RUSSIA 20.3%
UNITED STATES 18.6%
FRANCE 7.9%
CANADA 5.0%
HUNGARY 4.6%
ITALY 4.6%
ARGENTINA 4.0%
GERMANY 3.9%
TURKEY 3.9%
SPAIN 3.2%
REMAINDER 24.0%
WORLD PRODUCTION
3.908.000.000 BUSHELS

FIG. 3.—World wheat production before the war. Satisfactory statistics of production since the war are not available from some important producing countries. (U. S. Dept. Agr. Yearbook 1921, page 82.)

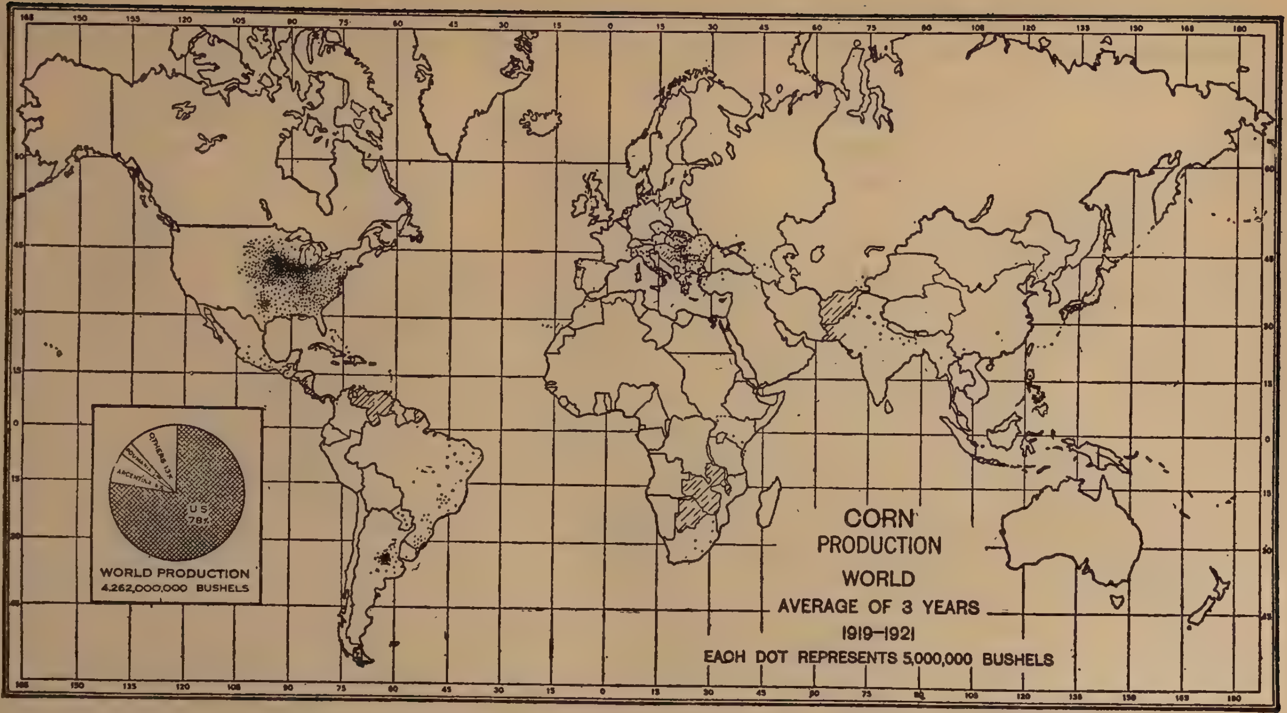

CORN
PRODUCTION
WORLD
AVERAGE OF 3 YEARS
1919–1921
EACH DOT REPRESENTS 5,000,000 BUSHELS
OTHERS 13%
ROUMANIA
ARGENTINA
U S 78%
WORLD PRODUCTION
4,262,000,000 BUSHELS

FIG. 4.—World corn production for the three year period 1919-1921. (U. S. Dept. Agr. Yearbook 1921, page 167.)

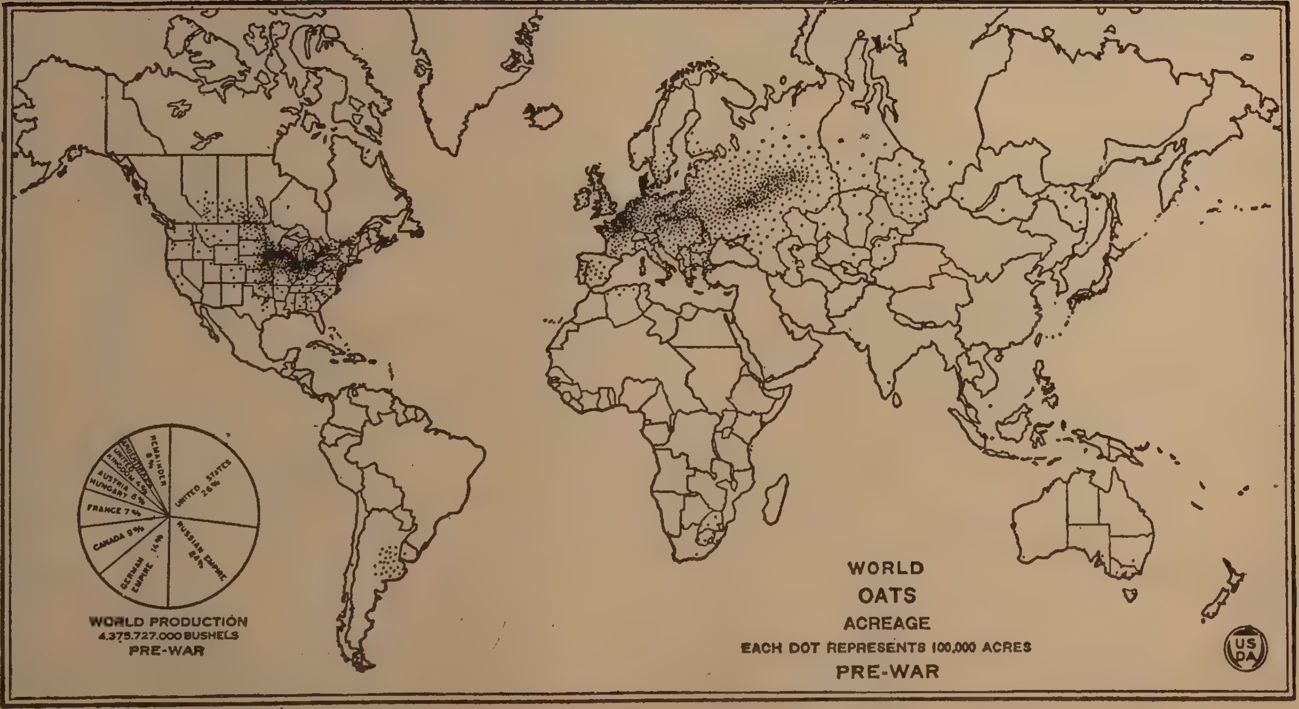

WORLD
OATS
ACREAGE
EACH DOT REPRESENTS 100,000 ACRES
PRE-WAR
UNITED STATES 26%
RUSSIAN EMPIRE 24%
GERMAN EMPIRE 14%
CANADA 9%
FRANCE 7%
AUSTRIA HUNGARY 6%
UNITED KINGDOM 4%
ARGENTINA
REMAINDER 8%
WORLD PRODUCTION
4.375.727.000 BUSHELS
PRE-WAR
US DA

FIG. 5.—World pre-war oat acreage. (U. S. Dept. Agr. Yearbook 1922, page 473.)

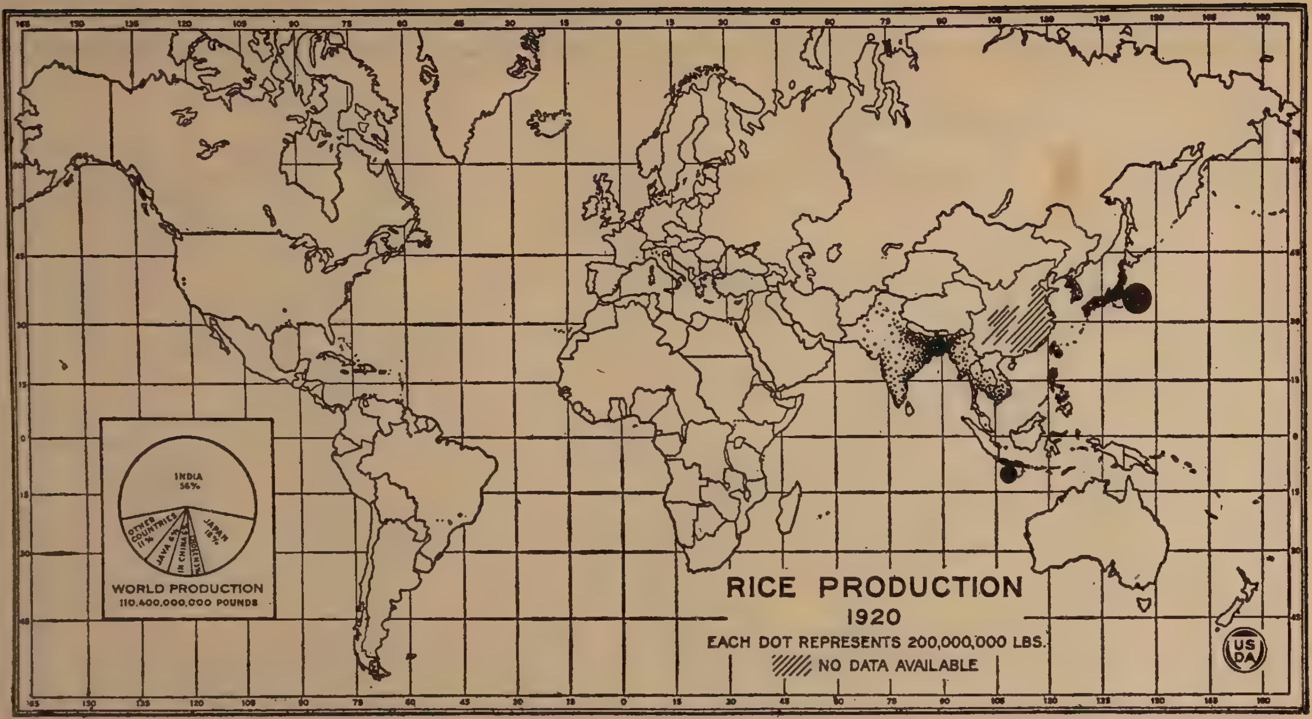

RICE PRODUCTION
1920
EACH DOT REPRESENTS 200,000,000 LBS.
▨ NO DATA AVAILABLE
WORLD PRODUCTION
110,400,000,000 POUNDS
INDIA 56%
JAPAN 18%
JAVA 6%
IN CHINA
OTHER COUNTRIES 11%

Fig. 6.—World centers of rice production. (U. S. Dept. Agr. Yearbook 1922, page 513.)

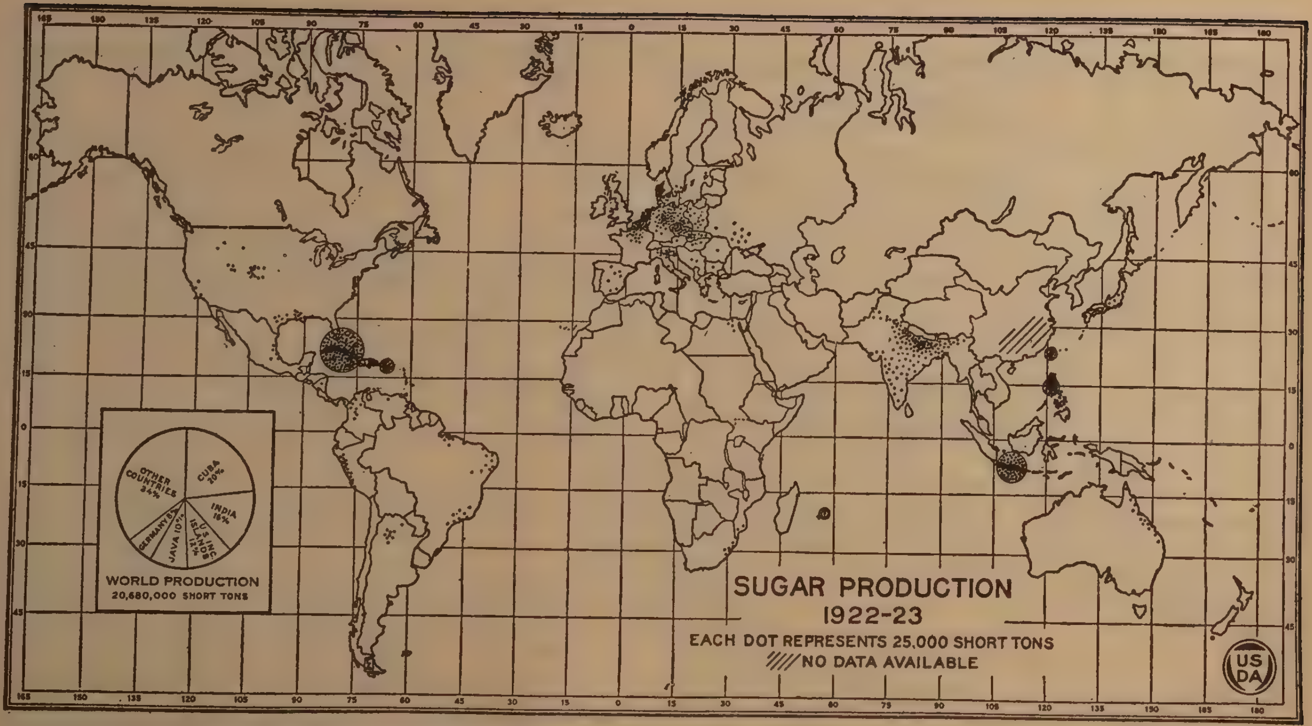
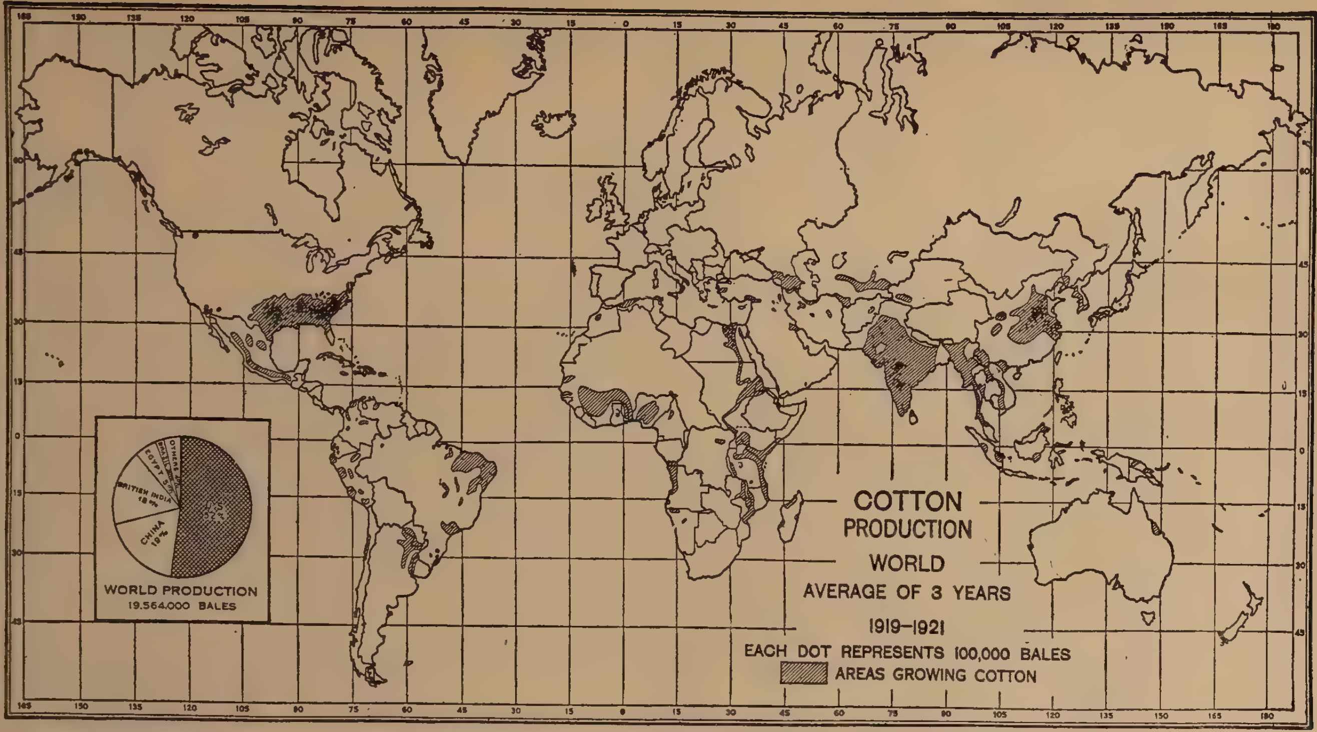

SUGAR PRODUCTION
1922-23
EACH DOT REPRESENTS 25,000 SHORT TONS
NO DATA AVAILABLE
WORLD PRODUCTION
20,680,000 SHORT TONS
CUBA 20%
INDIA 16%
U.S. INC. ISLANDS 12%
JAVA 10%
GERMANY 8%
OTHER COUNTRIES 34%
USDA

FIG. 7.—World sugar production, 1922-1923. During the past decade production has increased most rapidly in tropical countries and particularly in Cuba. (U. S. Dept. Agr. Yearbook 1923, page 214.)



COTTON
PRODUCTION
WORLD
AVERAGE OF 3 YEARS
1919–1921
EACH DOT REPRESENTS 100,000 BALES
▨ AREAS GROWING COTTON
OTHERS
BRAZIL
EGYPT 5%
BRITISH INDIA 18%
CHINA 19%
WORLD PRODUCTION
19.564.000 BALES

FIG. 8.—World cotton production, 1919-1921. The United States produces over half of the world's cotton crop. (U. S. Dept. Agr. Yearbook 1921, page 326.)

g. Cotton. This crop is produced in many parts of the world. The United States produces over half of the world crop, with India and China next in order. Cotton requires a long season of warm weather for growth and maturity.

h. Flax. This crop is grown both for seed and for fiber. Before the World War Russia was producing over 60 per cent of the flax fiber of the world. In the production of seed Argentina, India, Russia, and central North America are important centers. The production of seed flax has shown a steady decrease not only in the United States but also throughout the world. It is possible that the recent production of superior and particularly of wilt-resistant varieties may result in a revival of this crop.

36. Export of Surplus. Reference has already been made to the changes which have occurred through a period of years in the relative importance of exports from and of imports into the United States. The local consumption or utilization of products in these centers of production must have serious consideration, for it is the surplus of the different sections which determines world prices.

The United Kingdom has been the chief destination of staple crop exports from the United States. The percentage of the imports into the United Kingdom coming from the more important exporting countries of the world as shown under *36a* indicate roughly the chief competitors in the world's market for a number of the most important crops and crop products. Changes and trends in the percentage of total imports of these important crops coming from the United States and from the other countries indicated will be of particular interest.

36a. Per cent of the total imports into the United Kingdom coming from each country.

COUNTRY	WHEAT		CORN		COTTON		BACON	
	Average 1909-1913	1923	Average 1909-1913	1923	Average 1909-1913	1923	Average 1909-1913	1923
United States	13.2	8.9	16.3	15.7	75.2	51.7	38.6	36.3
Canada	28.2	53.8	1.3	2.3	...	...	9.2	10.7
Argentina	14.3	18.3	54.7	57.3	...	...	...	...
Australia	10.5	6.1	...	...	...	...	...	...
Russia	13.3	...	9.0	...	...	...	...	...
British India	16.4	10.7	...	...	3.3	1.0	...	...
Roumania	.8	...	12.8	4.1	...	...	...	...
Egypt	...	...	...	...	17.6	26.9	...	...
Peru	...	...	...	...	1.2	1.0	...	...
Brazil	...	...	...	...	1.3	1.6	...	...
Denmark	...	...	...	...	...	...	45.4	45.3
Other countries	3.2	2.3	3.9	20.6	1.4	19.8	6.8	7.7

The United Kingdom obtained from the United States 92.3 per cent of her hams in 1909 and 92.7 per cent in 1923, and from Canada 7 per cent and 6.5 per cent, respectively. During these two periods the United States supplied 88.5 per cent and 89.4 per cent of her tobacco, while Turkey, Greece, and India supplied most of the remainder.

37. Trends in Production and Exports, U. S. The United States produces over three-fourths of the world's corn crop, and exports about 1 per cent of this. Of the world's cotton crop, the United States produces 50 per cent and exports 60 per cent of its production. While it produces over 4 times as much wheat and 70 times as much corn as Argentina, the latter country is supplying the United Kingdom with over twice as much of her wheat imports as the United States and 4 times as much corn. The total exports of the United States for the more important crop products, also the per cent of the total crop represented in our exports, is shown under *37a.*

37a. The average annual exports from the United States, by periods, of eight important products; also, the per cent of the total production represented in exports.[17]

Crop	1909-1913		1914-1919		1923	
	Per Cent	Quantity	Per Cent	Quantity	Per Cent	Quantity
Wheat (bu.)....	15.2	56,913,000	27.9	152,980,000	19.9	78,793,000
Corn "	1.5	39,810,000	1.3	37,313,000	0.7	21,186,000
Oats "	0.7	8,304,000	6.3	86,303,000	0.1	1,149,000
Barley "	4.3	7,896,000	11.8	23,987,000	5.7	11,209,000
Rye "	2.4	855,000	31.3	19,555,000	28.1	17,705,000
Cotton (bales).	67.8	8,840,000	52.2	6,401,000	58.5	5,899,000
Tobacco (T.) ..	39.4	196,091	37.4	230,811	40.1	298,815
Meat and meat products (T.).	8.7	708,273	13.1	1,138.293	9.7	1,083,764

Factors Responsible for the Limitation of Our Crop Areas

38. Climate. Several factors combine to concentrate into limited areas that portion of the earth's surface which may be used in growing crops. Chief among these factors is climate. Associated with the climatic factor and influenced largely by it are several others, such as the soil and topography of the land. Transportation problems and markets are also to be reckoned with and may be important factors.

In a given area the soil may be so poor that crops cannot be grown. Often these areas are the result of destructive climatic agencies—the fertility may have been leached away by rains or carried away through erosion.

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[17] *Summary of Statistics of Agricultural Exports and Imports. No. 2.* Bureau of Agri. Econ., U. S. Dept. Agr., Aug., 1924.

The topography of the land—hills and valleys—is caused primarily by climatic agencies. Terracing, leveling, and fertilizing may be used to bring parts of these areas into a state of productivity if and when the demand for the products which may be produced warrants the expense and labor involved. While handicaps to crop production due to topography are not always insurmountable, those sections unsuitable for growing crops because of unfavorable temperature or rainfall offer greater obstacles and cannot easily be made productive.

39. Rainfall. Where the annual rainfall is less than ten inches, it is practically impossible to grow crops without irrigation, regardless of the topography, market, or fertility of the soil. At the other extreme it will be noted that excessive rainfall is not found in our great crop producing areas. The average annual rainfall in various parts of the world is shown in Fig. 9.

40. Temperature. Of the climatic agencies influencing plant growth, temperature probably is most important. The effect of temperature on plant growth may be modified by several factors, such as the duration of high or low temperatures, rapidity of temperature changes, moisture supply, and humidity. Each plant has its preferred temperature range, its optimum as well as minimum; and a maximum beyond which it will not grow and may even be killed. The 50° F. isotherm line of daily mean temperature marks the polar limit of most crops and trees, while all of our great crop areas are found between the 50° F. and the 68° F. isotherms.

The temperature has a marked effect on the relative humidity. With no change in the moisture content in the air the relative humidity is dependent on the temperature; a high relative humidity when the temperature is low and a low humidity when the temperature is high. With the lowering of the temperature the relative humidity may reach the saturation point when a part of the moisture will condense from the air in the form of dew or frost. When the temperature of the objects on which moisture condenses is at or below the freezing point frost is formed instead of dew.

While temperature limits crop areas more definitely than does moisture, moisture materially modifies the effect of the temperature. Both moisture and temperature conditions must be favorable for the successful growing of crops, as either alone can limit production.

41. Temperature Belts. The 1924 *Yearbook of the United States Department of Agriculture* gives the following general grouping based on temperature:

"1. Tropical Belt, with all months warm, temperature averages over 68 degrees F. Extends broadly from 20 degrees N. to 16 degrees S. latitude with a rainy and dry, or two rainy and two dry, seasons

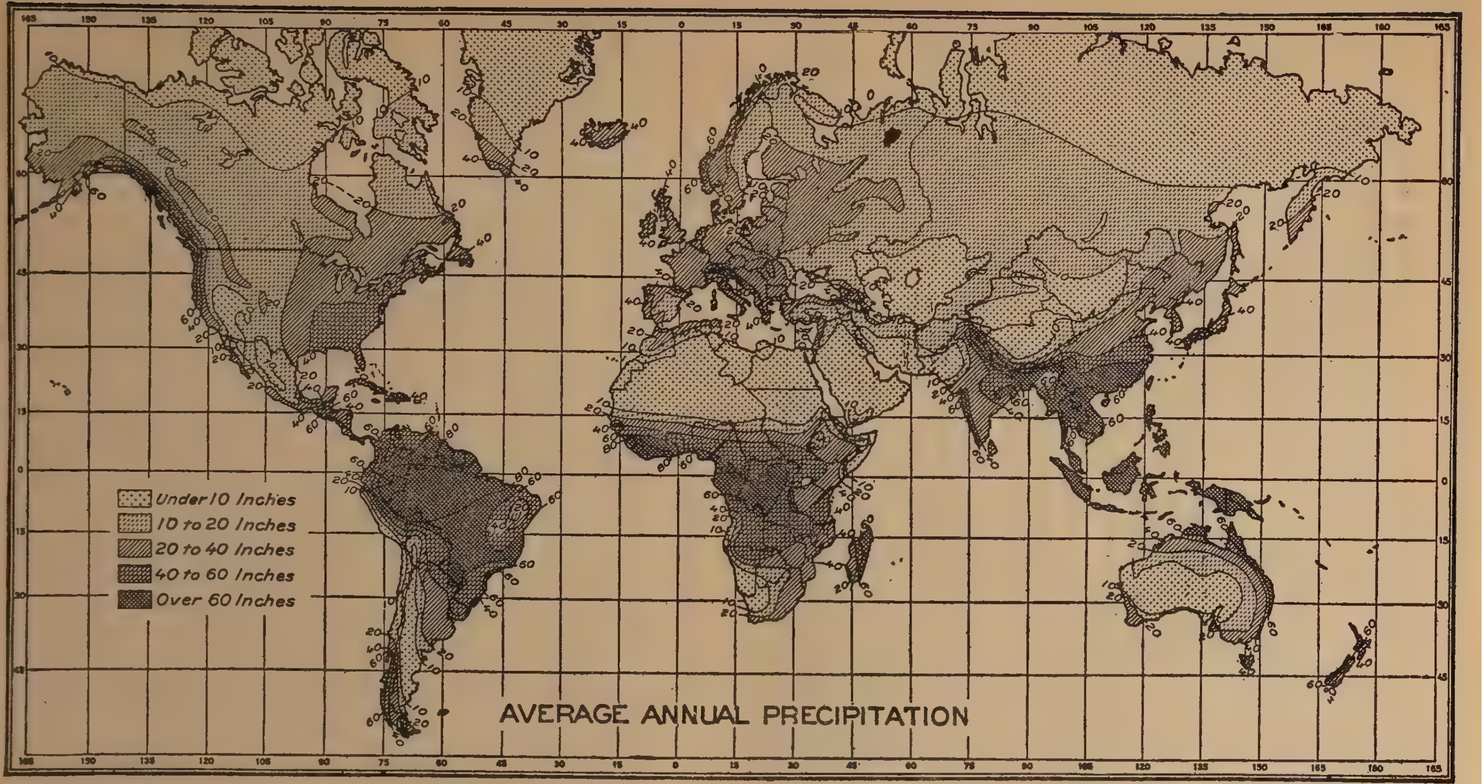

AVERAGE ANNUAL PRECIPITATION
Under 10 Inches
10 to 20 Inches
20 to 40 Inches
40 to 60 Inches
Over 60 Inches

FIG. 9.—The average annual precipitation in different parts of the world. (U. S. Dept. Agr. Yearbook 1924, page 465.) *To what extent does precipitation correlate with the natural vegetation shown in Fig. 2? With important crop producing centers?*

during the year. Rainfall is mostly heavy although there are some desert regions. Common crop plants are: breadfruit, ginger, sago, coffee, sugar cane, cotton, bananas, manioc, rice, and corn. The people of this zone are generally at a low stage of civilization.

"2. Subtropical belts, with 4 to 11 months warm weather averaging over 68 degrees F. These belts lie immediately north and south of the tropical belt. The rainfall varies from a short dry, and a long rainy season on the margin of the equatorial belt to a long dry, and a short rainy season due to the trade winds. The savannas (grassy open spaces) are found here between forests on one side and deserts on the other. Frequent famines are experienced.

"3. Temperate belts, with 4 to 12 months of moderate temperature between 50 degrees and 68 degrees F. This includes the greater part of the United States and its crops and practices are familiar to all.

"4. Cold belts, with 1 to 4 months temperate and the rest below 50 degrees F. Evergreen, deciduous forests, small grains, corn, and short season crops are grown.

"5. Polar belts, with all months averaging below 50 degrees F. These belts are outside the limit of tree and cereal growth. Mosses and lichens are found in this region where the temperature is below 50 degrees F. in the warmest months."

STUDY QUESTIONS ON CHAPTER I

1. "The food supply will be a regulating factor on population increase, in the world within 25 years." Present points favorable to and those opposed to the truth of this statement.
2. Do you believe a greater effort should be made to keep country-reared boys on farms and to bring agricultural college graduates back to the farms? Why?
3. Do you believe that the movement of farm folks to the city has serious consequences? Why?
4. How would you suggest that a boy desirous of farming get a start in the business? Contrast with boys of 50 years ago.
5. You are interested in stimulating people to change to a new type of food. How can this best be done? Illustrate by a change or an attempt to bring about such a change in recent years.
6. What factors indicate the intensity of farming? Contrast an intensively and an extensively farmed area.
7. Classify the countries of the world into intensive, medium and extensively farmed areas.
8. Trace the use of land by man from the most extensive use, through various types of farming to the most intensive use.
9. Why are large areas of abandoned land found in the South and in the eastern part of the United States, and not in other sections?

10. Compare the average crop yields in the wheat belt with those of other sections. Account for this condition.
11. Criticize the statement, "Farms steadily grow smaller and but little machinery is used in the section of the world farmed for the longest period, therefore, we may expect to see less machinery used in the future than at present."
12. Make a report indicating the relative importance of the countries competing with the U. S. in the wheat markets of the world.
13. In a study of world crop production, outline the status and importance of areas competing directly with the United States in the production of similar staple crops.
14. Locate the great staple crop areas of the world. What factors are common to these areas?
15. List the factors limiting crop producing areas and outline the extent to which these may be modified by man.
16. Why is the yield of wheat in the U. S. as low as it is, having in mind the higher average yields in some other countries?
17. Account for the fact that in the central eastern corn belt states the average yield of corn, wheat, oats, and potatoes has not been increased to as great an extent as in the states further east.
18. "Corporation farming is the chief hope of farming people for progress and equality of opportunity and reward." Present points for and against this idea.

APPLICATION ASSIGNMENTS ON CHAPTER I

1. Assume the following situation: In 1630 a ship containing settlers intended for Jamestown was blown out of its course and wrecked on the coast of a treeless, grassy island containing 10 square miles. The livestock and machinery were saved but only four men and four women remained alive. The island was not discovered until a few years ago. Outline the changes in the type of farming and the rules and regulations designed to preserve the colony from starvation. Considering a normal rate of increase in population write the agricultural history of this group.
2. Criticize the above situation as a parallel to the position of humanity in general, in relation to the land area and the food supply of the world.
3. Assume that you own 160 acres of land and are offered a reasonable price for it, payable in amply protected shares in a good coöperative corporation farm, directed by a man in whom you have confidence and who is the best manager and farmer you know. The corporation is to elect directors and operate on a large scale, guaranteeing you your share of the returns. Three factories will be operated in which the workmen will be employed when not busy on the farms. Will you sell? State your reasons fully.

CHAPTER II

CROP DISTRIBUTION IN THE UNITED STATES

In considering the world distribution of crops, and factors influencing such distribution, considerable attention was given to the distribution of crops in the United States as illustrating the relationships discussed. In this chapter we propose to consider the distribution and relative importance of field crops in this country and the more important causes which are, or have been, operative.

42. Agricultural Use of Land. The three most important agricultural uses of land are: (1) the production of harvested crops such as corn, alfalfa, and cotton, (2) the pasturing of stock of all kinds and (3) the growing of timber—forestry. The abundant supply of land in America apparently has led us to assume that our resources for these purposes are unlimited. However, conservationists have shown us the folly of our wastefully destructive attitude toward forests and forest lands. The government has taken steps to prevent destructive over-grazing of the public lands. The land that can be used for crops either is being used at the present time or its use involves so much labor and expense that even the abnormally high prices which prevailed during the World War and immediately subsequent to it did not result in bringing large additional areas into use. A consideration of the use that we are making and can make of our land area is of great importance in considering possible agricultural developments of the future.

The Present and the Possible Future Use of Our Land Areas

43. Present Use of Land Areas. Harvested crops occupy about one-fifth of the land area of the United States, forests and cut-over land about one-fourth, and pasture land (exclusive of temporary crop pasture and forest lands used incidentally for pasture) occupy about forty-three per cent. A graphic presentation of the uses being made of our land areas is found in Fig. 10. Many of the figures indicated in the graphs are, of necessity, estimates.

44. Uses for Greatest Productivity. Considering the physical character of our land area, the potential or possible uses to which it might be put to secure the greatest productivity are shown graphically in Fig. 11.

The area classed as forest land is that land which is so rough and sandy that it is valuable only for forestry purposes. Pasture land includes the arid lands and lands too rough for crops but suitable for grazing. The remainder is crop land although a considerable part of it probably will not be used for harvested crops.

45. Area Suitable for Crop Production. The nine hundred and seventy-three million acres indicated in Fig. 11 as physically capable

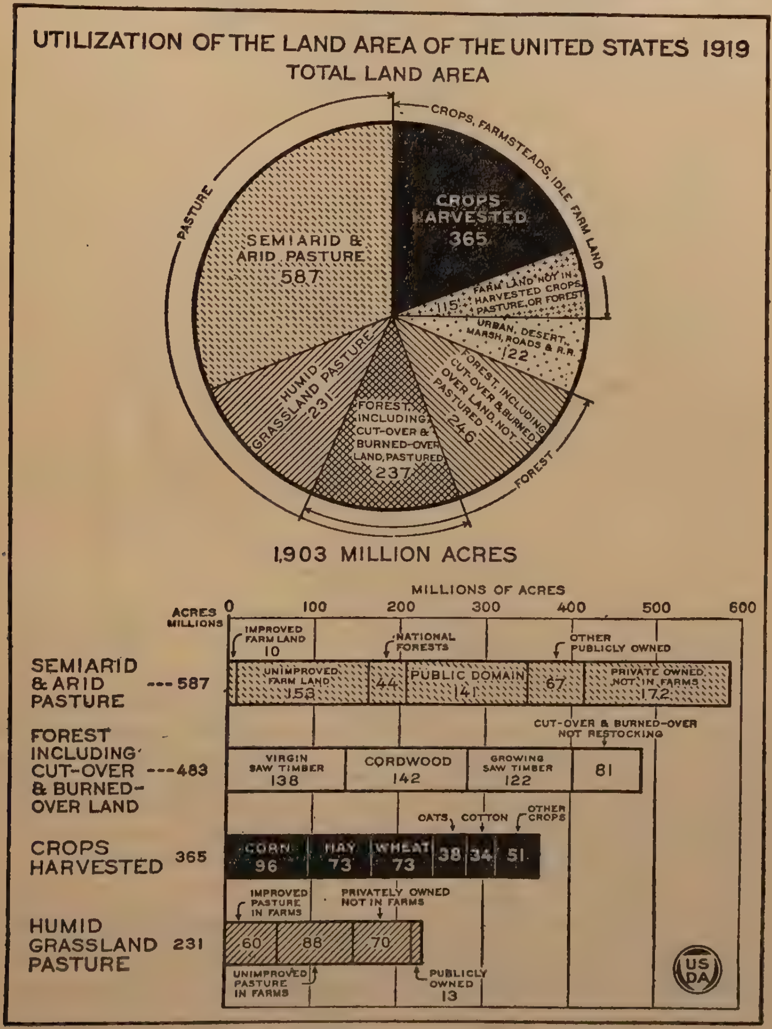


Fig. 10.—Harvested crops occupied 19 per cent of the land area of the United States in 1919. Pasture, exclusive of temporary crop pasture and forest land used incidentally for pasture, occupied 43 per cent, and forest and cut-over land about 25 per cent of the total area. Many of the figures in this graph are necessarily estimates. (U. S. Dept. Agr. Yearbook 1923, page 416.)

of producing crops may be further divided as shown in Fig. 12. This includes practically all of the land which is not too rough, rocky, sandy, cold, or dry for the growing of crops and which is not being used for non-agricultural purposes—cities, roads, etc. Some of this land will not be used for crops even with maximum population. Much of the land which now is being used for pasture and other land which probably will be so used in the future is included in this acreage. Most of these figures are based on estimates. Fig. 12 also suggests a possible reason for this land not being in crops at present and suggests the obstacles to be overcome before it will be put into harvested crops.

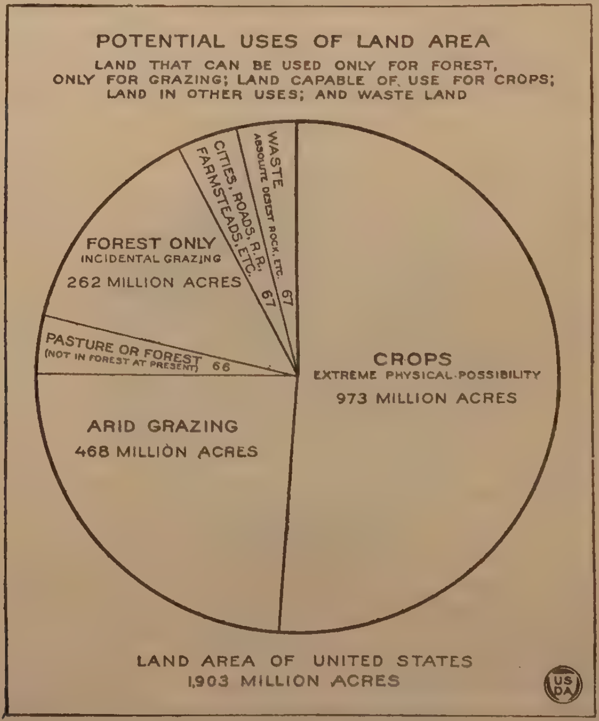


Fig. 11.—Land capable of use for crops is estimated at about 973 million acres but this includes some land which it will not be economical to crop even when we reach our maximum population. Approximately 382 million acres are humid lands of which 262 million are so rough or sandy that the land is primarily valuable only for forest, and 66 million acres are too rough for cultivation but are used for pasture and are not forested at present. (U. S. Dept. Agr. Yearbook 1923, page 431.)

46. Per Cent of Cropped Land in Different Areas. Our interest lies chiefly in the land in crops. The location of this land in the

United States is shown in Fig. 13. Over five-sixths of the improved land of the United States is in the humid eastern half. Nearly two-thirds is included in a rough triangular shaped area with its corners in the states of North Dakota, Pennsylvania and Texas. While only about one-fourth of the land of the United States is included in this area, it produces four-fifths of the corn, three-fourths of the wheat and oats, and three-fifths of the hay of the nation. There is no other area of equal size in the world which possesses conditions so favorable to the growing of corn, and there are few so favorable to the production of small grains and hay as this region.

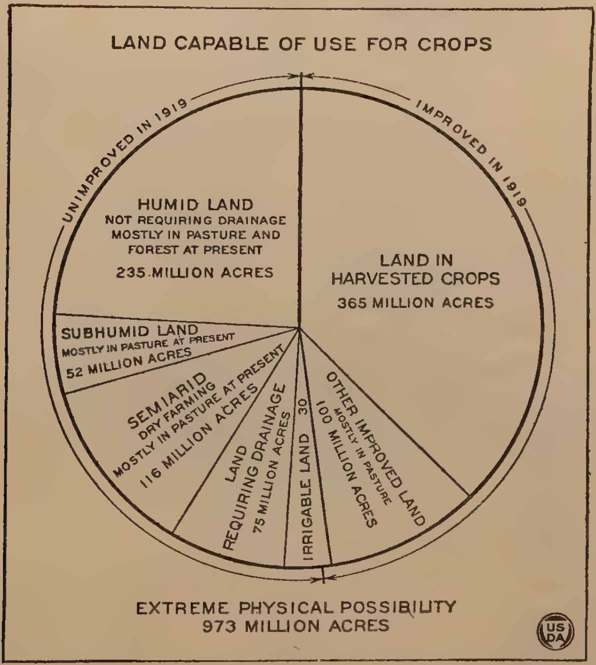


FIG. 12.—The land capable of being used for the production of crops and the present condition of such land is shown in this graph. (U. S. Dept. Agr. Yearbook 1923, page 427.)

FACTORS AFFECTING CROP DISTRIBUTION

47. Factors Which Restrict Crop Areas. Within each of the world's great crop regions, various climatic, soil, and economic factors tend to confine each crop to rather restricted areas. These factors are presented for the United States so that each particular crop belt may be studied with reference to the causes for its location.

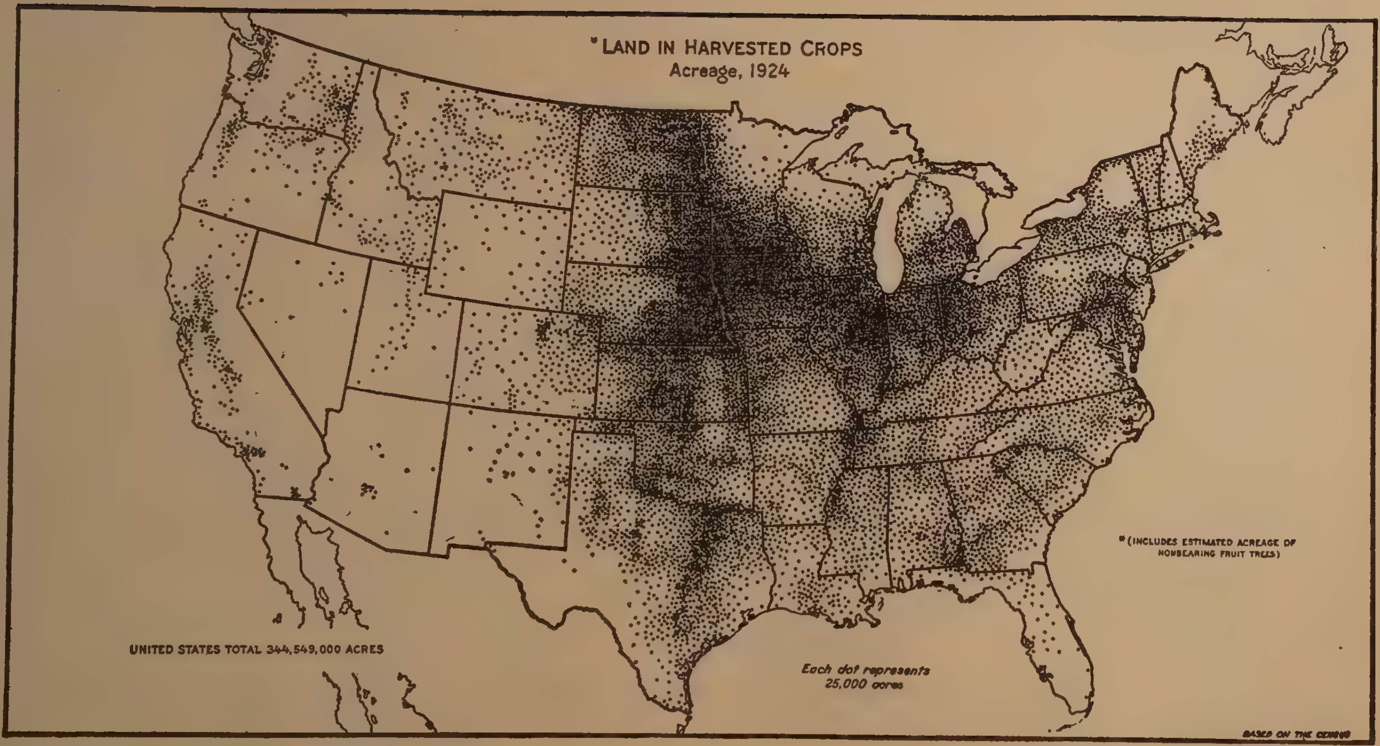

*LAND IN HARVESTED CROPS
Acreage, 1924
*(INCLUDES ESTIMATED ACREAGE OF NONBEARING FRUIT TREES)
UNITED STATES TOTAL 344,549,000 ACRES
Each dot represents 25,000 acres
BASED ON THE CENSUS

FIG. 13.—The per cent of improved land to total land area in different parts of the United States is indicated by the land in harvested crops. (U. S. Dept. Agr. Yearbook 1928, page 642.)

The more important factors which will be considered are: (1) rainfall, (2) humidity, (3) temperature, (4) length of growing season, (5) sunlight, (6) character of the soil, and (7) economic factors.

48. Rainfall. We all recognize the fact that the moisture available for crop growth results from the rainfall and snowfall. However, not all of the water which falls as rain or snow is absorbed by the soil and not all of that which is absorbed is used by the plants.

The distribution of the rainfall tends to limit the production of crops, perhaps more than any other single factor. The average annual precipitation in each section of the United States is shown in Fig. 14. The rainfall varies in its efficiency, depending on the time of year that it falls. In some sections a considerable part of the rain falls during the months when crops are dormant or when there are no crops on the land. At this time the ground may be frozen, resulting in a large part of the water running off the surface. Fifteen inches of precipitation in North Dakota may be expected to give approximately the same result in crop production as 25 inches in southern Texas, owing to the fact that in the South the rains are more torrential and the evaporation much greater. The proportion of the rainfall which falls during the growing season of the crop is important. This distribution is shown in Fig. 15 for the crop-growing season, April to September, inclusive.

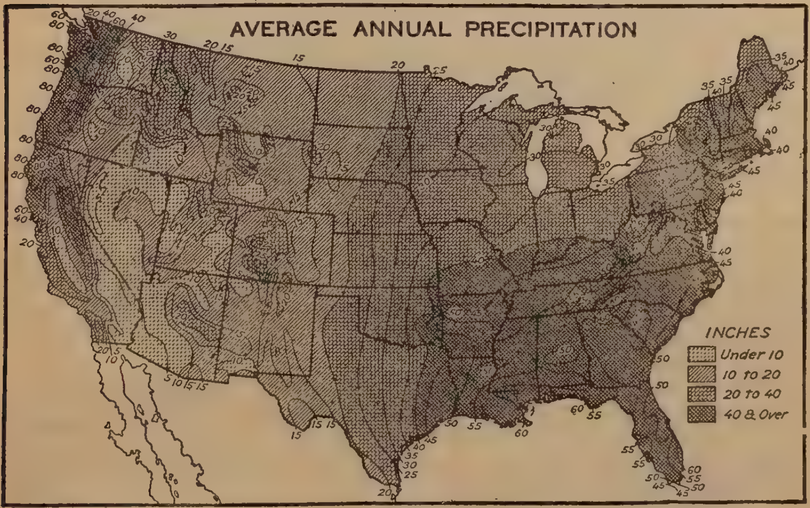


FIG. 14.—Annual precipitation in different parts of the United States. (U. S. Dept. Agr. Yearbook 1924, page 479.) *It is said that 15 inches of rainfall in North Dakota is as effective in crop production as 25 inches in Texas. Is this true? Explain.*

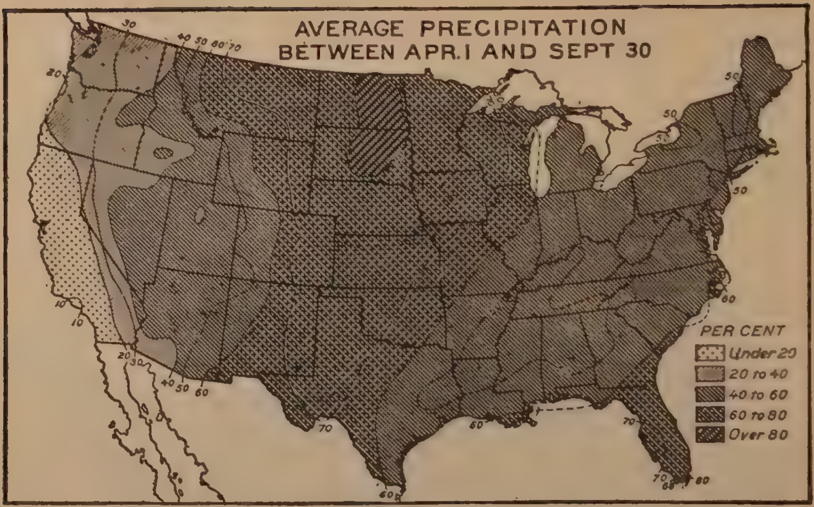
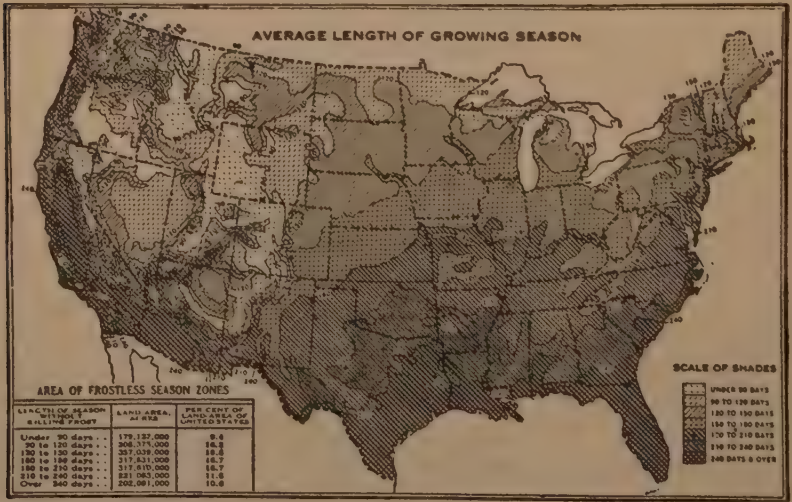

AVERAGE PRECIPITATION
BETWEEN APR. 1 AND SEPT 30
PER CENT
Under 20
20 to 40
40 to 60
60 to 80
Over 80
10
20
30
40
50
60
70
80

FIG. 15.—The per cent of the annual precipitation that occurs during the six warmer months of the year. (U. S. Dept. Agr. Yearbook 1924, page 480.) *Under what condition is the seasonal distribution of rainfall of much greater importance than the annual precipitation?*

It will be noted that in the far West only a small per cent of the heavy annual rainfall comes during the cropping season, with most of


AVERAGE LENGTH OF GROWING SEASON
SCALE OF SHADES
UNDER 90 DAYS
90 TO 120 DAYS
120 TO 150 DAYS
150 TO 180 DAYS
180 TO 210 DAYS
210 TO 240 DAYS
240 DAYS & OVER

AREA OF FROSTLESS SEASON ZONES

LENGTH OF SEASON WITHOUT KILLING FROST	LAND AREA, ACRES	PER CENT OF LAND AREA OF UNITED STATES
Under 90 days . .	179,137,000	9.4
90 to 120 days . .	308,375,000	16.2
120 to 150 days . .	357,039,000	18.8
150 to 180 days . .	317,831,000	16.7
180 to 210 days . .	317,610,000	16.7
210 to 240 days . .	221,063,000	11.6
Over 240 days . .	202,091,000	10.6

FIG. 16.—The average length of the growing season as measured by the number of days free from frost in different parts of the United States. (U. S. Dept. Agr. Yearbook 1921, page 419.) *Does the number of days free from frost measure the season in which the grower can safely depend upon crops to mature? Explain.*

it concentrated in the winter. In the East the distribution is rather uniform throughout the year. Throughout the Great Plains area, in parts of which the precipitation is scanty and the seasonal distribution, therefore, of great importance, from 70 to over 80 per cent falls during those months when it is of the greatest benefit to crops.

49. Humidity. The term "relative humidity" refers to the per cent of the total amount of water which the air can hold at a given temperature. A saturated atmosphere is represented as having a relative humidity of 100. The relative humidity is influenced largely by the temperature, the wind, and the amount of moisture available. It has an important influence or effect on the amount of water lost by evaporation. Table *49a* gives the average relative humidity at different points in the United States for representative months and also for the year.[1] The amount of moisture carried by the air may have more to do with the crops which can be grown most successfully than is readily apparent. An inch of rain in one section may be equal to two under other conditions.

49a. Annual average humidity at different points in the United States; also for certain months. (8:00 *A.M. and* 8:00 *P.M.*)

	JAN.	APR.	JULY	AUG.	OCT.	ANNUAL
Grand Rapids, Mich.	89 85	78 64	76 57	81 63	85 71	82 70
Helena, Mont.	73 67	66 42	62 33	60 31	68 50	68 50
Red Bluff, Calif.	88 71	75 41	50 18	52 20	66 37	70 43
Salt Lake City, Utah	75 70	58 38	45 24	47 27	58 45	60 45
North Platte, Nebr.	81 86	78 49	82 52	84 53	80 52	81 56
Davenport, Ia.	85 78	75 57	76 56	80 60	81 63	80 65
Washington, D. C.	76 68	69 59	77 71	80 74	81 72	76 68
Atlanta, Ga.	81 70	74 59	83 70	85 72	77 61	79 65
Yuma, Ariz.	56 32	54 19	63 27	67 30	59 28	59 27

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[1] U. S. Dept. Agr. Weather Bur.—*Monthly Weather Review.* Supp. No. 6, pp. 19-25. 1917.

50. Humidity and Evaporation. The influence of humidity on evaporation may be seen from Table *50a,* which gives the annual relative humidity and the evaporation from a free water surface for each of a number of places in the United States.[2]

50a. The relative humidity and the annual evaporation in inches at various points in the United States; also, the number of years for which the evaporation data are available.

Location	Relative Humidity	Evaporation	
		Yrs.	In.
Ariz., Tucson	41.6	3	54.2
Cal., Northern	86.0	2	25.3
Cal., Central	66.0	4	49.2
Cal., Southern	29.7	1	71.8
Colo., Ft. Collins	54.0	15	29.3
Colo., Rocky Ford	48.7	1	61.6
Kansas, Central	67.7	3	45.2
Kansas, Western	52.0	2	59.9
Mich., Detroit	74.4	4	32.1
Neb., Lincoln	70.0	11	34.8
Neb., North Platte	66.0	3	41.3
N. J., New Brunswick	80.0	2	29.5
N. Mex., Santa Fe	45.0	1	55.0
Ohio, Cleveland	72.9	6	24.6
S. D., Pierre	64.0	2	38.0
Wash., Prosser	76.2	2	27.6
Wyo., Laramie	53.7	7	39.4

51. Temperature. The importance of temperature on crop distribution is well recognized. The temperature determines to a greater extent than any other single factor the length of the rest period and of the growth period of plants. The limits of crop belts agree to a considerable extent with the temperature.

Crops may be divided broadly into cool climate crops and warm climate crops. The cool climate crops include such crops as potatoes, wheat, oats, buckwheat, flax, and most of the grasses; while cotton, corn, rice, sugar cane, peanuts, velvet beans, sweet potatoes, and watermelons are representative of the warm climate crops. Low temperatures in the spring and fall with accompanying frosts serve to mark the limits of the growing season.

52. Length of the Growing Season. The number of days between the average date of the last killing frost in the spring and of the first killing frost in the fall represents the length of the average growing season. Crops may have their growing season shortened by other factors than frost; for example, in a certain section an extended drought may serve to limit the growing season for a given crop. The length of the growing season as determined by frost for various parts of the United States is shown in Fig. 16.

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[2] Henry, A. J.—"Climatology of the United States." *U. S. Dept. Agr. Weather Bur. Bul. Q.* 1906.

53. Sunlight. The third significantly important climatic factor in determining crop distribution is sunlight. Under field conditions each plant group has an optimum light requirement. The actual number of hours of light necessary to supply this optimum may vary with the intensity of the light and with its duration. The intensity of the light during ordinary clear days is above the optimum for many plants. In the corn belt the light of a normal clear July day is thought to be too intense for the optimum growth of corn. The chief natural variations in light intensity in given locations are brought about by cloudy weather. The possible amount of sunshine for the year is approximately the same in all sections.

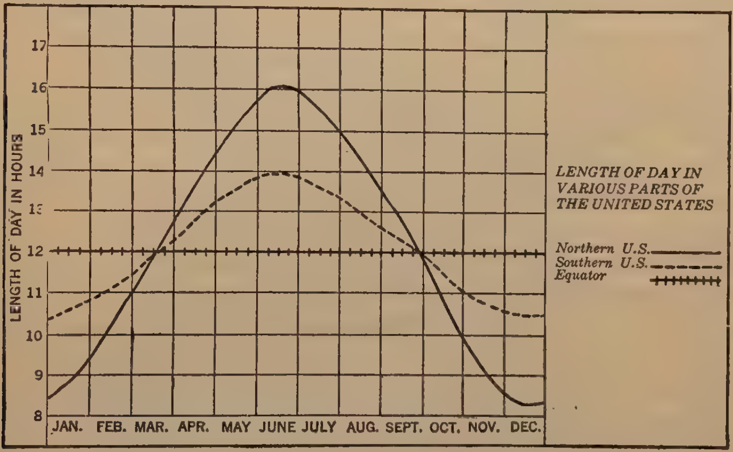

FIG. 17.—Average hours per day by months in the northern part of the United States and in the southern part; also at the equator. (The length of day actually varies somewhat at the equator.)

54. Length of Day. The range in the length of day, or hours of sunlight each day, varies from an almost constant 12 hours of light and 12 hours of darkness at the equator to almost 6 months of light and 6 months of darkness at the poles. The range in the length of day in the northern part and in the southern part of the United States is shown graphically in Fig. 17.

The duration of light recently has acquired a new significance due to the studies of Garner and Allard, of the United States Department of Agriculture, which indicate that the hours of sunlight which a plant receives each day is a vital factor in accounting for the plant's behavior and distribution.[3] A certain variety of tobacco when planted in the field in Maryland would not set seed, but when planted in the greenhouse in the fall flowered and set seed readily. The seed setting was attributed to the short daylight period prevailing during the fall months.

Theoretically, each crop has an optimum range in length of day during which it will make a vegetative or top growth, another optimum range during which it will make root growth, and another range during which it will bloom and ripen. The overlapping of these ranges does not make them any less real or lessen their effect. In addition to optimum ranges, each plant also has a formative period of a certain duration through which it must pass before reproduction or seed formation can take place.

The distribution of the different varieties of a particular crop and of different crops, especially the time of their maturity, may be partially accounted for on the basis of the length of day to which they are exposed. Considerable study is needed before we can arrive at the real value of this theory, along with others suggested, as an explanation of the phenomenon of change of type of growth and maturity.

55. The Character of the Soil. The topography of the land tells something of the soil. Rough hilly land is not so likely to be fertile as prairie soil with equal rainfall. The fertility of the soil is lost both by leaching and by erosion, and erosion is greatest in hilly sections.

56. Native Vegetation. The native vegetation found on the land in various parts of the United States is shown in Fig. 18. Forests, including semi-arid woodland, originally covered about 900,000,000 acres in the United States, of which about 350,000,000 acres have been cleared for agriculture, and as many more cut over or devastated. About 600,000,000 acres were clothed originally with grass, interspersed with herbaceous plants, of which about 200,000,000 acres have been plowed for crops, or for pasture in rotation with crops, including about 7,000,000 acres irrigated. Desert vegetation covered 400,000,000 acres, of which about 12,000,000 acres have been reclaimed by irrigation. Perhaps one-half of the remaining forest and woodland is pastured, as is practically all of the grassland and much of the desert.

57. Soil Regions. Soils in large general areas resemble each other sufficiently to be classified in rather broad soil regions. The soil regions in the United States are shown in Fig. 19.

A rather striking relationship between the limits of the native

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[3] Garner, W. W., and Allard, H. A.—"Effect of the Relative Length of Day and Night and Other Factors of the Environment on Growth and Reproduction in Plants." *Jour. Agr. Res.* Vol. 18, No. 11, pp. 553-606. March 1. 1920.

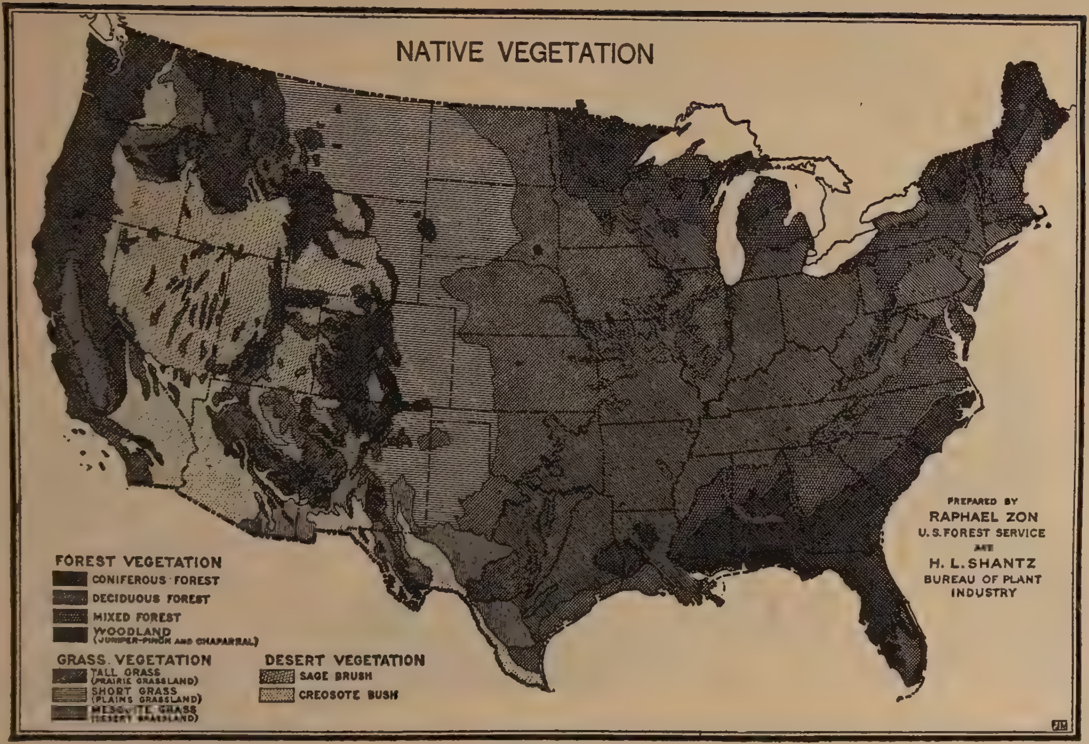
NATIVE VEGETATION
FOREST VEGETATION
CONIFEROUS FOREST
DECIDUOUS FOREST
MIXED FOREST
WOODLAND (JUNIPER-PINON AND CHAPARRAL)
GRASS VEGETATION
TALL GRASS (PRAIRIE GRASSLAND)
SHORT GRASS (PLAINS GRASSLAND)
MESQUITE GRASS (DESERT GRASSLAND)
DESERT VEGETATION
SAGE BRUSH
CREOSOTE BUSH
PREPARED BY
RAPHAEL ZON
U.S. FOREST SERVICE
AND
H. L. SHANTZ
BUREAU OF PLANT INDUSTRY

FIG. 18.—The distribution of native forest, grass, and desert vegetation in the United States is shown in the map herewith. About 600 million acres were originally clothed with grass, some 200 million acres of which have been plowed and cropped. Of 400 million acres of desert about 12 million have been reclaimed by irrigation. Originally, approximately 900 million acres in the United States were covered with forest, of which approximately 350 million have been cleared for agriculture while as many more have been cut over or devastated. (U. S. Dept. Agr. Yearbook 1921, page 421.)

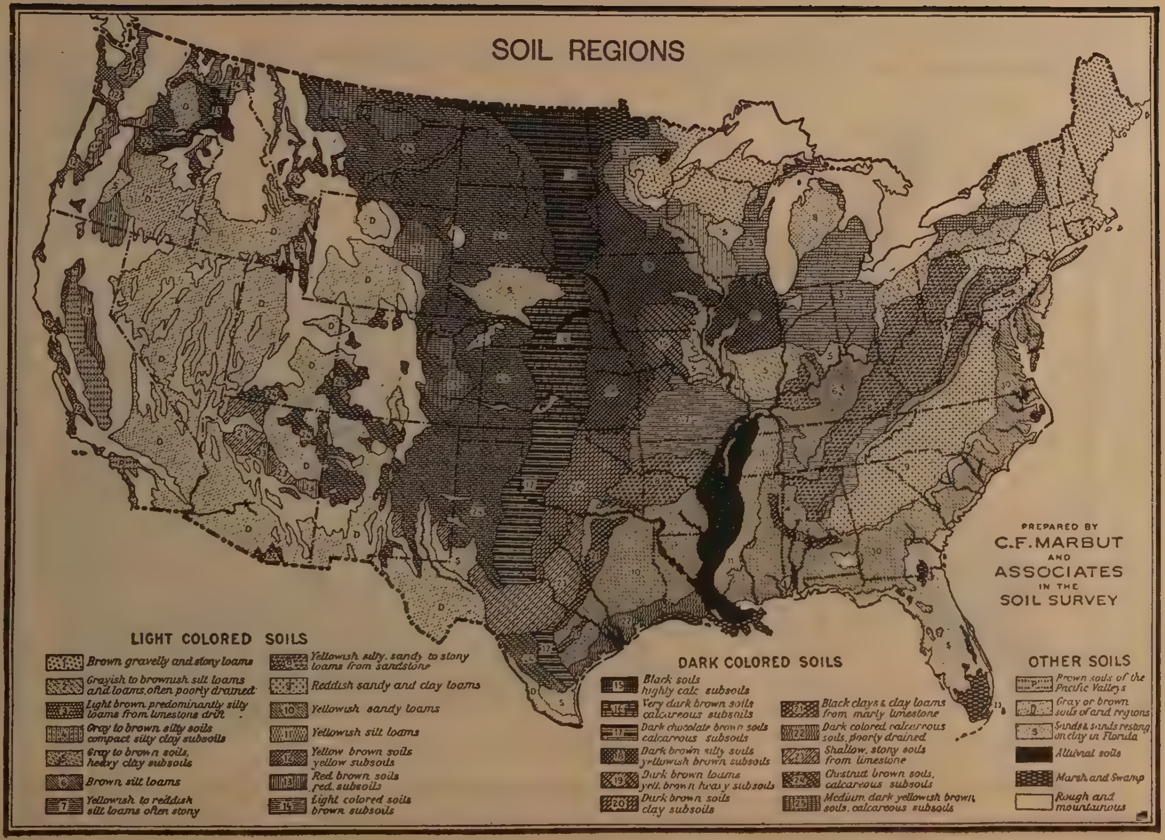
SOIL REGIONS
PREPARED BY
C.F. MARBUT
AND
ASSOCIATES
IN THE
SOIL SURVEY
LIGHT COLORED SOILS
1 Brown gravelly and stony loams
2 Grayish to brownish silt loams and loams, often poorly drained
3 Light brown predominantly silty loams from limestone drift
4 Gray to brown silty soils compact silty clay subsoils
5 Gray to brown soils, heavy clay subsoils
6 Brown silt loams
7 Yellowish to reddish silt loams often stony
8 Yellowish silty, sandy to stony loams from sandstone
9 Reddish sandy and clay loams
10 Yellowish sandy loams
11 Yellowish silt loams
12 Yellow brown soils yellow subsoils
13 Red brown soils red. subsoils
14 Light colored soils brown subsoils
DARK COLORED SOILS
15 Black soils highly calc. subsoils
16 Very dark brown soils calcareous subsoils
17 Dark chocolate brown soils calcareous subsoils
18 Dark brown silty soils yellowish brown subsoils
19 Dark brown loams yell. brown heavy subsoils
20 Dark brown soils clay subsoils
21 Black clays & clay loams from marly limestone
22 Dark colored calcareous soils, poorly drained
23 Shallow, stony soils from limestone
24 Chestnut brown soils, calcareous subsoils
25 Medium dark yellowish brown soils, calcareous subsoils
OTHER SOILS
P Brown soils of the Pacific Valleys
D Gray or brown soils of arid regions
S Sands & sands resting on clay in Florida
Alluvial soils
Marsh and Swamp
Rough and mountainous

Fig. 19.—The larger soil divisions are indicated on the map herewith. The light colored forest soils in the United States total about 800 million acres, the dark colored grass land soils about 600 million and the light colored arid soils about 500 million. Forest soils are normally light colored and are likely to be less fertile than those in regions of less rainfall. (U. S. Dept. Agr. Yearbook 1921, page 420.)

vegetation areas and soil regions will be noted, though a number of different soil regions may be included within a certain vegetation area.[4]

58. Economic Factors Affecting Crop Distribution. When a new section of country is opened up, it is often necessary to concentrate on certain crops, grown to be sold, so that the transportation costs may not be prohibitive. This factor is influencing crop distribution today in determining which crops farmers in certain sections will grow and which ones may be expected to be shipped in from other sections. For example, bulky crops such as hay are grown for the most part in regions where fed. Transportation with reference to perishable or semi-perishable products has been overcome largely by the advent of cold storage warehouses and refrigerator cars, but the cost of such transportation is a big factor in limiting production to certain regions. The acreage of many bulky crops, with relatively low unit values, such as sugar beets, must be confined to the vicinity of utilization or manufacture.

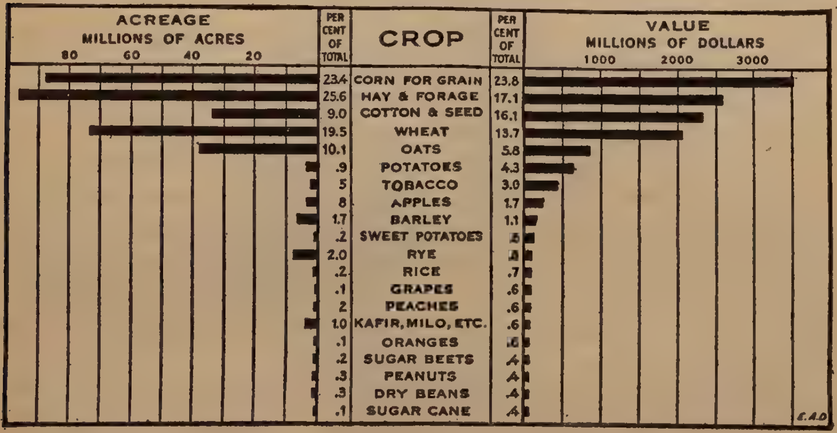

FIG. 20.—Relative importance of different crops in acreage and value for the United States, 1919.

The value of the land per acre is an economic factor affecting crop distribution. In sections where the land is high priced due to favorable climatic conditions, location as related to markets, or to speculation, certain crops with high acre values are grown. Such a crop as oats, which has a relatively low unit value, is not grown as the chief crop on high-priced land. Pasture or tillable land is plowed and planted to crops when the value of land demands a higher return.

The available supply of labor at critical periods may serve to limit the crops that will be grown. In choosing secondary crops it is necessary to eliminate those which require attention at the same time as do the principal crops. Examples of such principal crops are cotton or corn in their respective belts. The superior adaptation of one crop may limit the acreage, or entirely eliminate a similar crop.

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[4] *U. S. Dept. Agr. Yearbook* 1921, p. 420.

CROP AREAS IN THE UNITED STATES

59. Special Crop Areas. The areas of production of important field crops in the United States are shown in[5] Figs. 21 to 32. In studying these maps, one should note that they are not all made on a uniform basis. In some cases one dot represents the production of a certain number of tons, bales, bushels, or acres, while in another map each dot may represent an entirely different quantity or area. The distribution of dots on a particular map indicates quite accurately the relative importance of a given crop in different parts of the country, but the number of dots on different maps does not necessarily indicate the relative importance of the different crops.

The student of crop production will do well to give study to these maps so that, with the mention of any one of the crops shown, he will immediately picture in his mind the important producing center or centers and the range of production. The distribution of the different crops should be considered in their relation to one another. Fig. 33 gives a composite picture of the distribution of some of the more important crops.

By far the heaviest production of winter wheat is found in central Kansas, southern Nebraska and northern Oklahoma with the belt extending eastward through Illinois, Indiana, and Ohio to Maryland. Heavy spring wheat production centers in eastern North Dakota, northeastern South Dakota and western Minnesota. The greatest amount of rye is produced in central North Dakota and southern Michigan, with much less important centers in Wisconsin, Minnesota, and South Dakota.

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[5] *U. S. Dept. Agr. Yearbooks* 1923 and 1928.

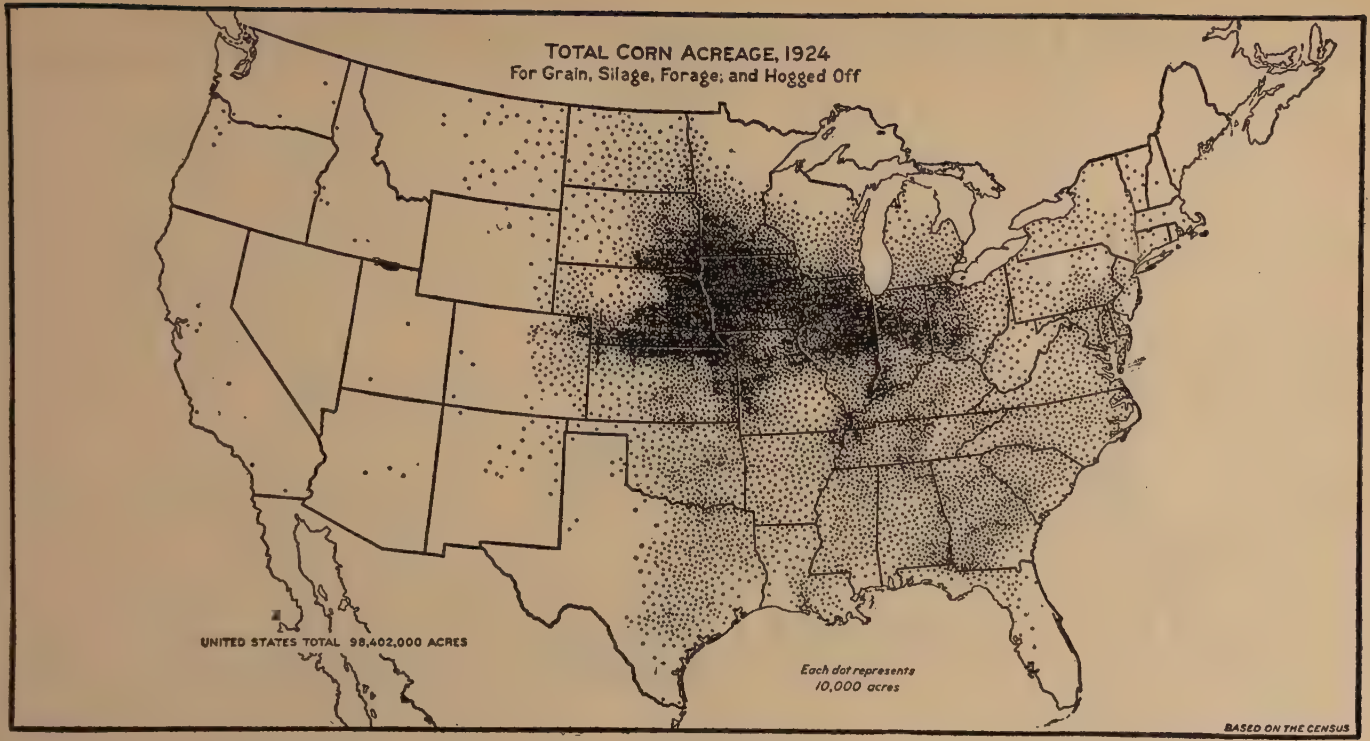

TOTAL CORN ACREAGE, 1924
For Grain, Silage, Forage; and Hogged Off
UNITED STATES TOTAL 98,402,000 ACRES
Each dot represents 10,000 acres
BASED ON THE CENSUS

FIG. 21.—Corn production in the United States for the year 1924. (U. S. Dept. Agr. Yearbook 1928, page 644.)

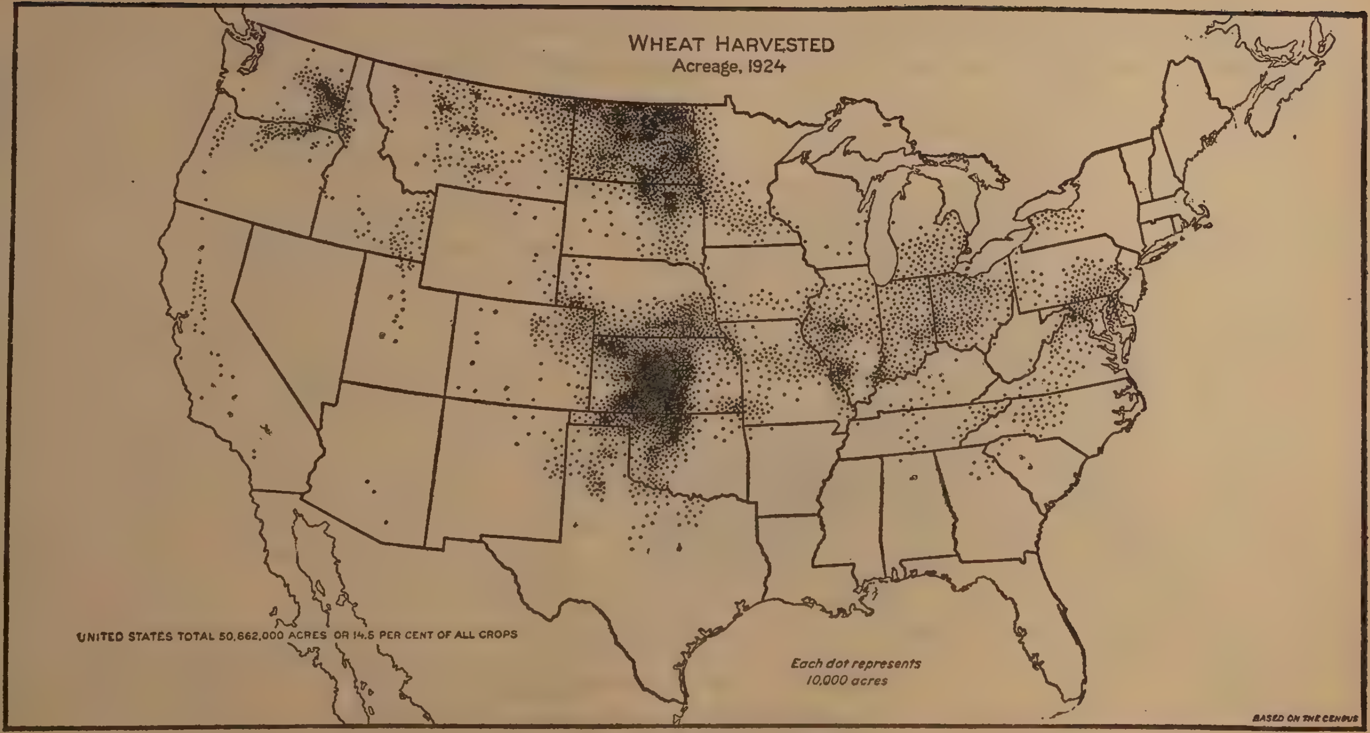

WHEAT HARVESTED
Acreage, 1924
UNITED STATES TOTAL 50,662,000 ACRES OR 14.5 PER CENT OF ALL CROPS
Each dot represents
10,000 acres
BASED ON THE CENSUS

FIG. 22.—Wheat acreage in the United States, 1924. (U. S. Dept. Agr. Yearbook 1928, page 645.)

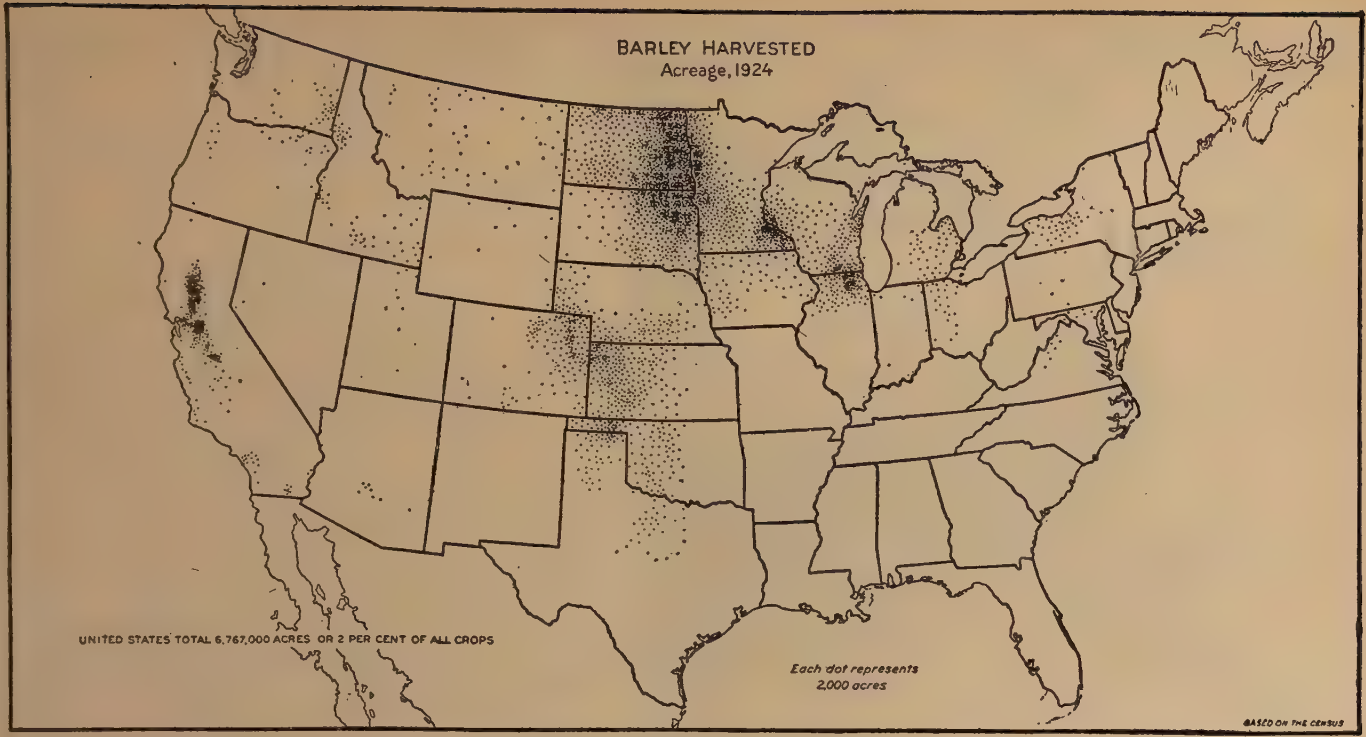

BARLEY HARVESTED
Acreage, 1924
UNITED STATES TOTAL 6,767,000 ACRES OR 2 PER CENT OF ALL CROPS
Each dot represents 2,000 acres
BASED ON THE CENSUS

FIG. 23.—Barley acreage in the United States, 1924. Each dot represents only one-fifth that shown on the wheat map. (U. S. Dept. Agr. Yearbook 1928, page 647.)

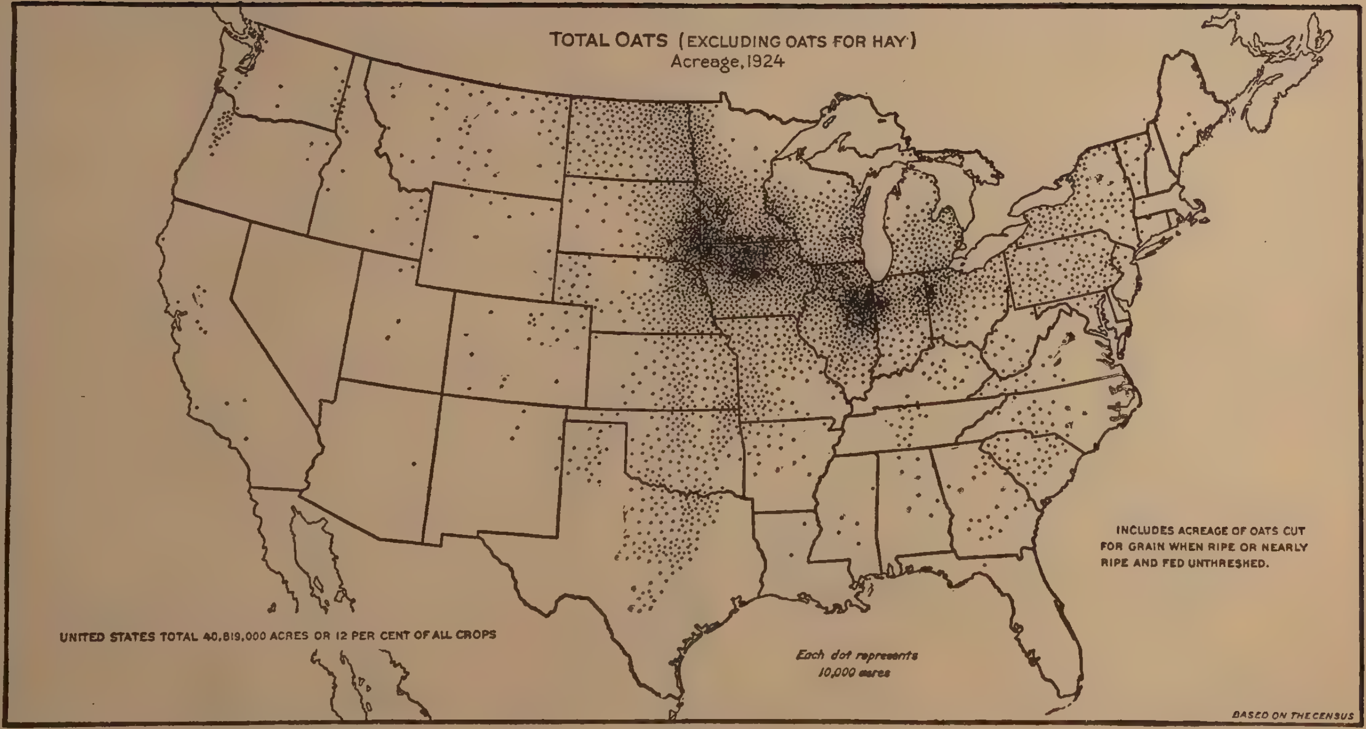

TOTAL OATS (EXCLUDING OATS FOR HAY)
Acreage, 1924
INCLUDES ACREAGE OF OATS CUT FOR GRAIN WHEN RIPE OR NEARLY RIPE AND FED UNTHRESHED.
UNITED STATES TOTAL 40,819,000 ACRES OR 12 PER CENT OF ALL CROPS
Each dot represents 10,000 acres
BASED ON THE CENSUS

FIG. 24.—Oat acreage in the United States, 1924. (U. S. Dept. Agr. Yearbook 1928, page 646.)

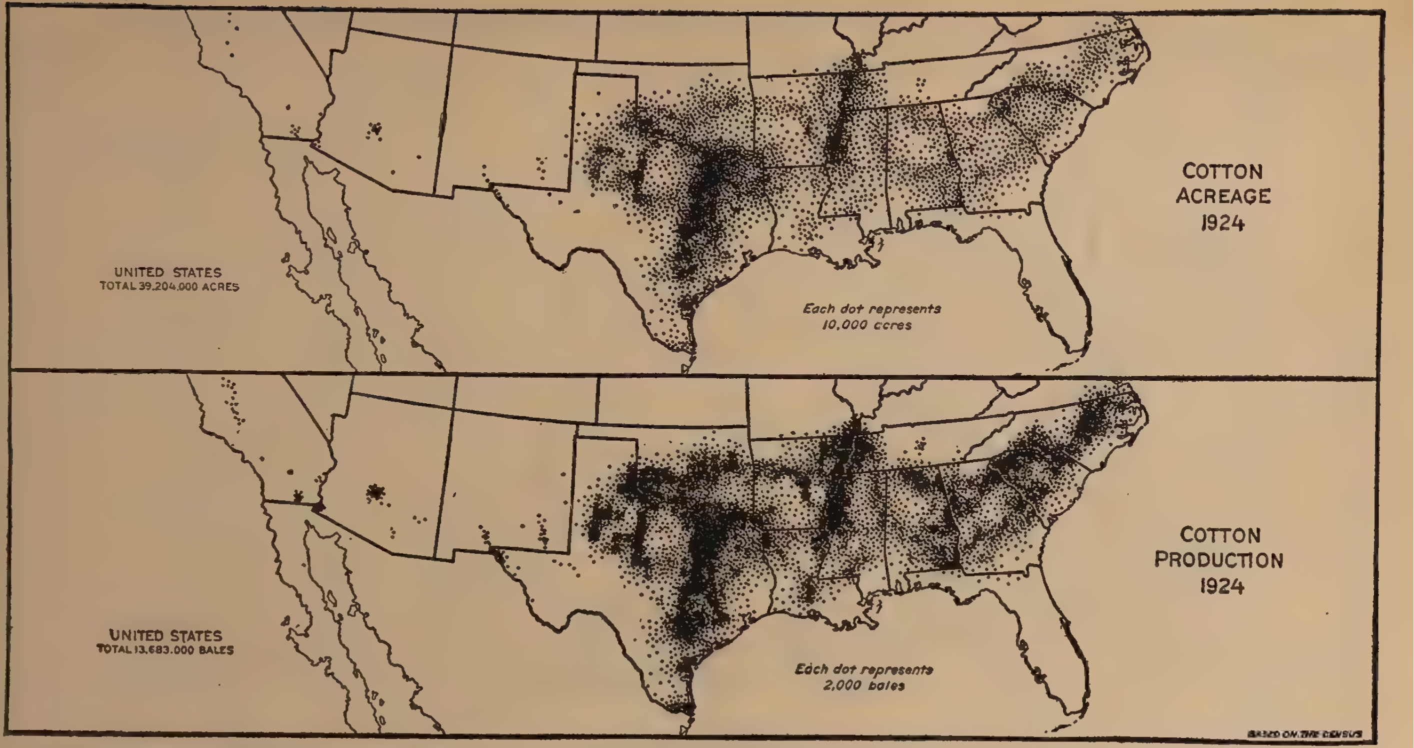

COTTON
ACREAGE
1924
UNITED STATES
TOTAL 39,204,000 ACRES
Each dot represents
10,000 acres
COTTON
PRODUCTION
1924
UNITED STATES
TOTAL 13,683,000 BALES
Each dot represents
2,000 bales
BASED ON THE CENSUS

FIG. 25.—Cotton acreage and production in the United States, 1924. (U. S. Dept. Agr. Yearbook 1928, page 643.)

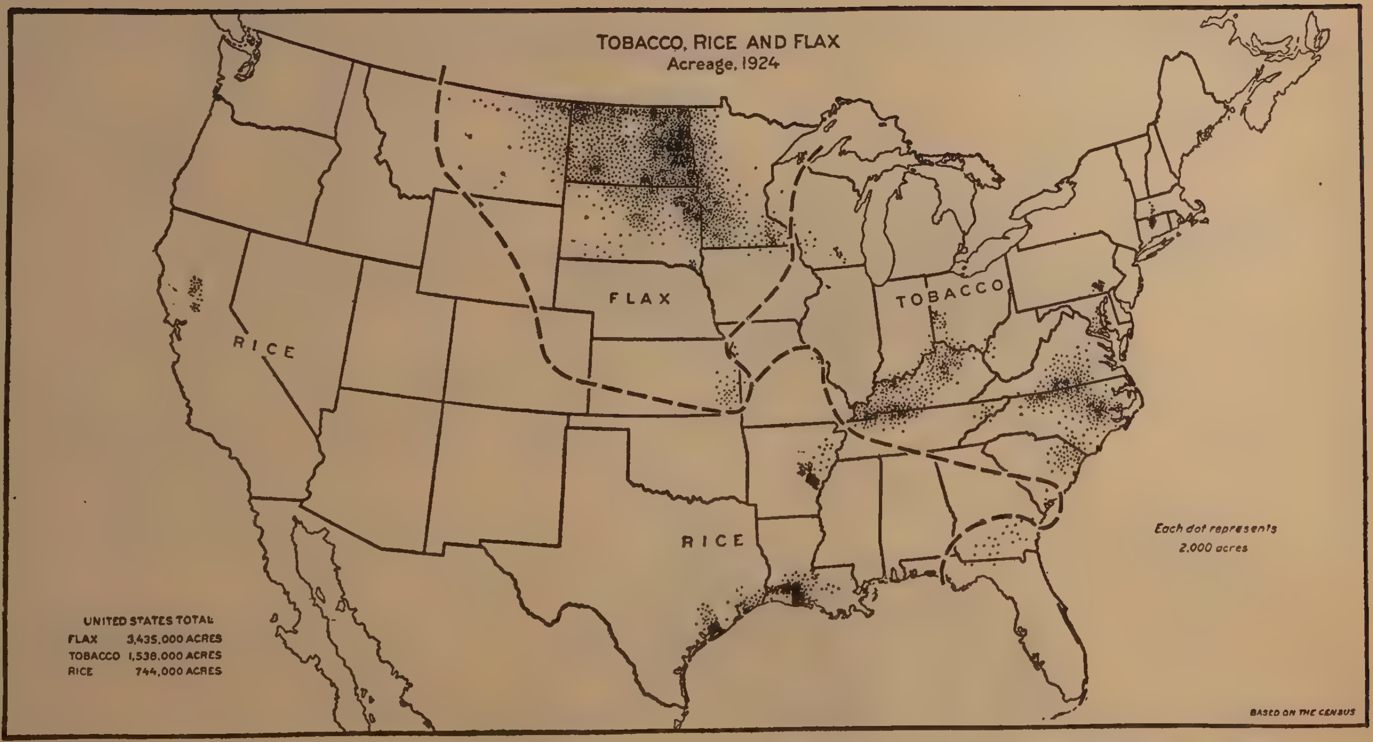

TOBACCO, RICE AND FLAX
Acreage, 1924
FLAX
TOBACCO
RICE
RICE
Each dot represents 2,000 acres
UNITED STATES TOTAL
FLAX 3,435,000 ACRES
TOBACCO 1,538,000 ACRES
RICE 744,000 ACRES
BASED ON THE CENSUS

FIG. 26.—Tobacco, rice and flax acreage in the United States, 1924. (U. S. Dept. Agr. Yearbook 1928, page 650.)

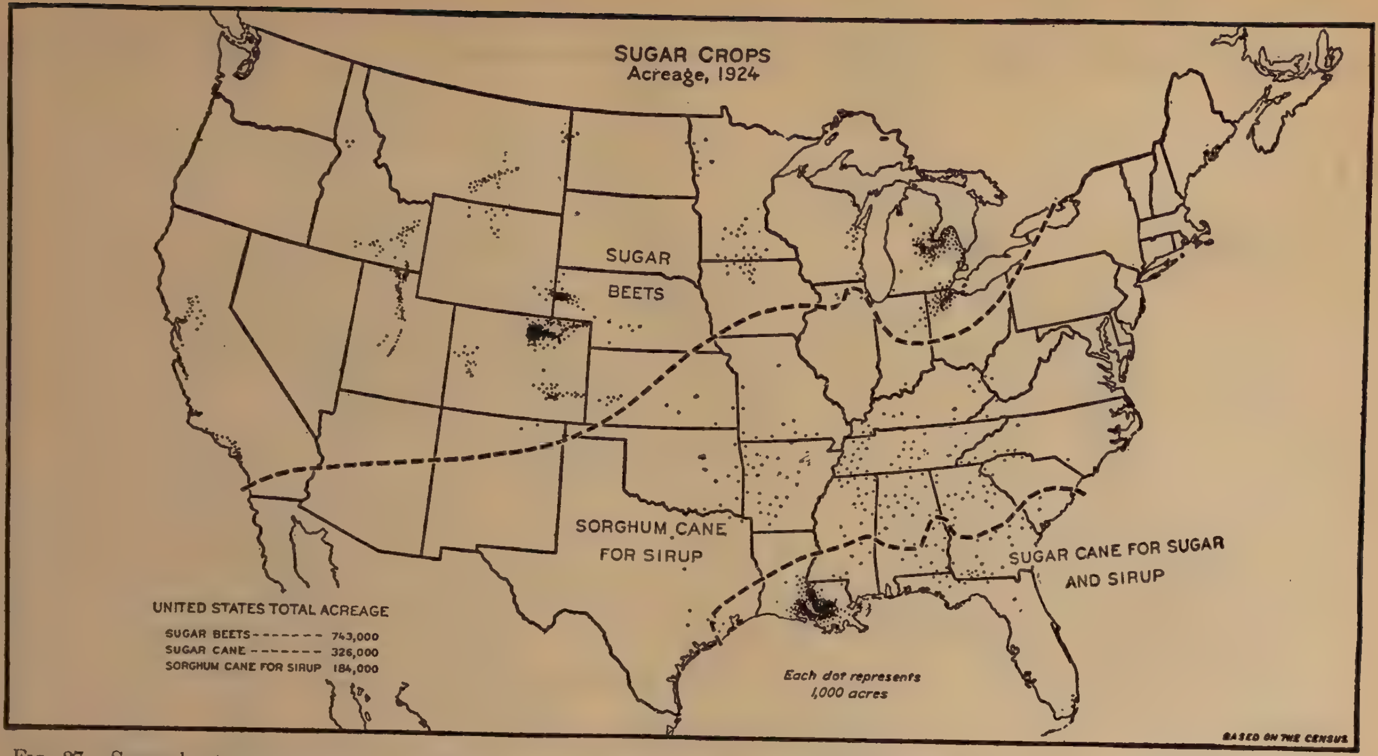

SUGAR CROPS
Acreage, 1924
SUGAR BEETS
SORGHUM CANE FOR SIRUP
SUGAR CANE FOR SUGAR AND SIRUP
UNITED STATES TOTAL ACREAGE
SUGAR BEETS - - - - - - - 743,000
SUGAR CANE - - - - - - - 326,000
SORGHUM CANE FOR SIRUP 184,000
Each dot represents 1,000 acres
BASED ON THE CENSUS

Fig. 27.—Sugar beet, sugar cane and sorghum cane acreage in the United States, 1924. (U. S. Dept. Agr. Yearbook, 1928, page 653.)

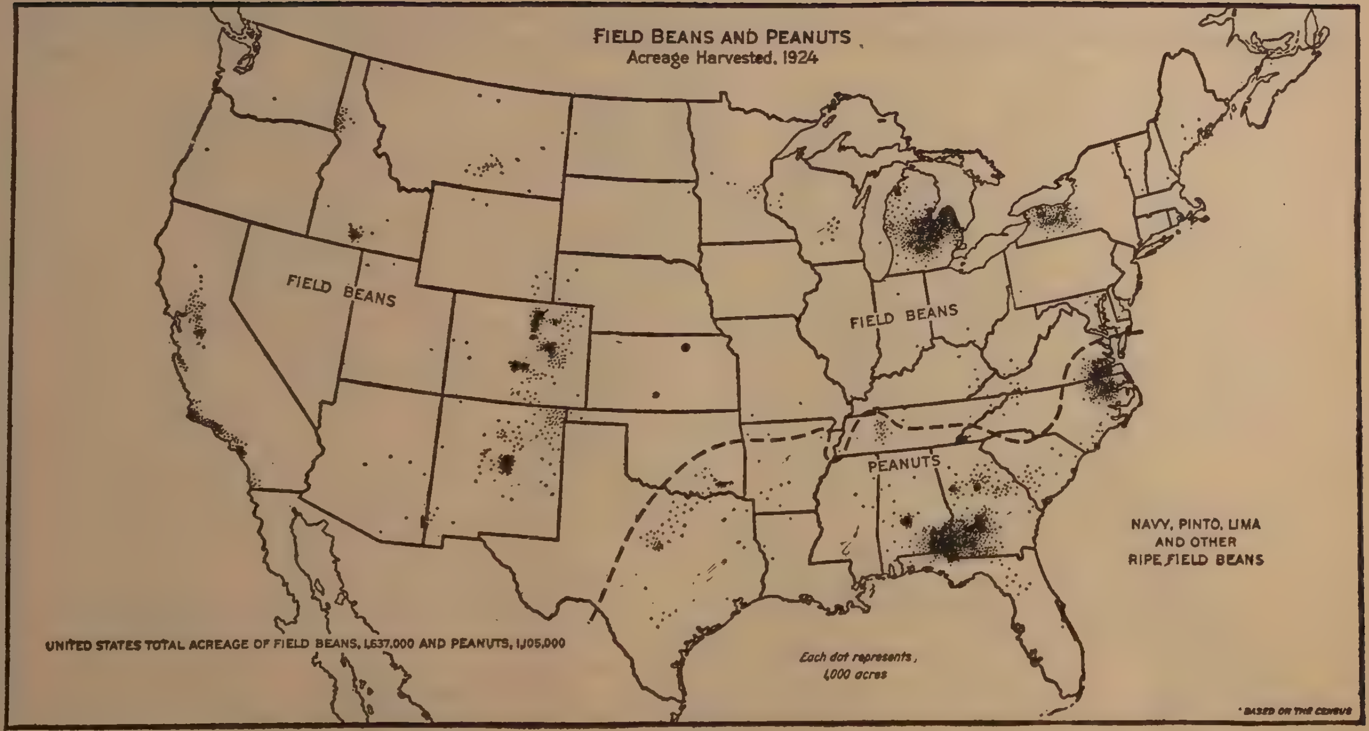

FIELD BEANS AND PEANUTS
Acreage Harvested. 1924
FIELD BEANS
FIELD BEANS
PEANUTS
NAVY, PINTO, LIMA
AND OTHER
RIPE FIELD BEANS
UNITED STATES TOTAL ACREAGE OF FIELD BEANS, 1,637,000 AND PEANUTS, 1,105,000
Each dot represents, 1,000 acres
BASED ON THE CENSUS

Fig. 28.—Acres of field beans and peanuts in the United States, 1924. (U. S. Dept. Agr. Yearbook 1928, page 652.)

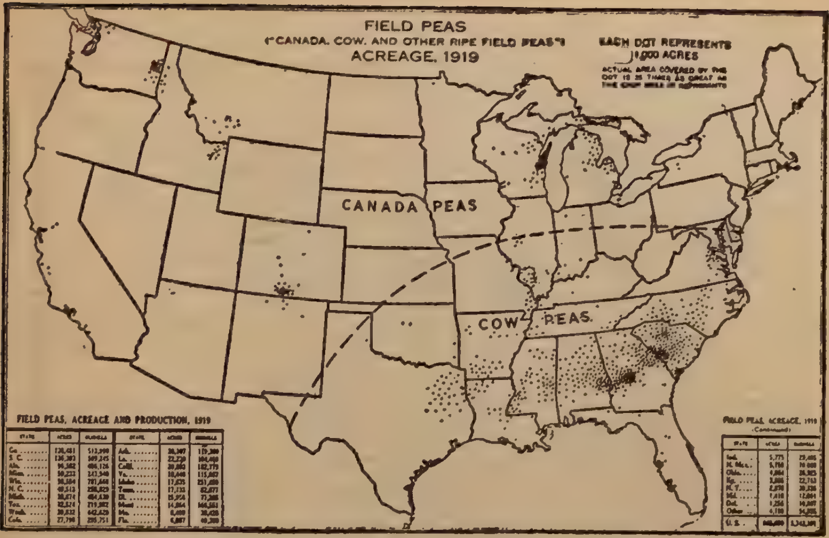

FIELD PEAS
("CANADA, COW, AND OTHER RIPE FIELD PEAS")
ACREAGE, 1919
EACH DOT REPRESENTS 1,000 ACRES
CANADA PEAS
COW PEAS
FIELD PEAS, ACREAGE AND PRODUCTION, 1919
FIELD PEAS ACREAGE, 1919 (Continued)

Fig. 29.—Acres of Canada field peas and cowpeas in the United States, 1919 (U. S. Dept. Agr. Yearbook 1921, page 454.)

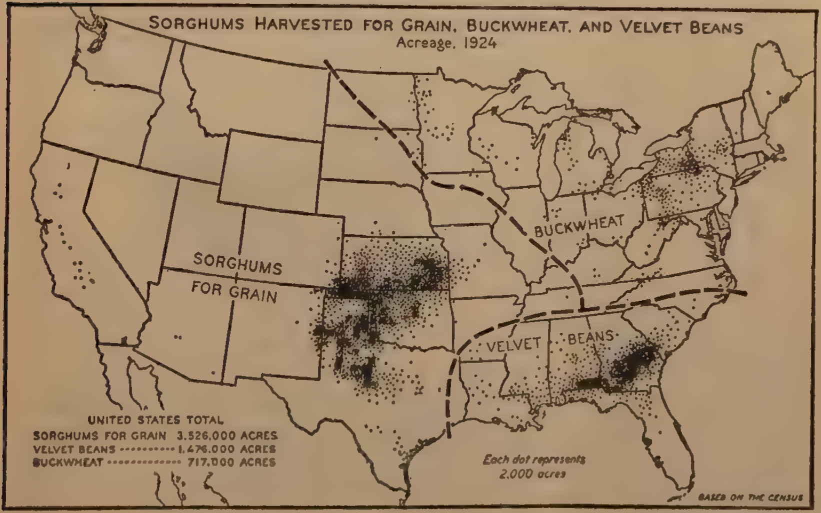
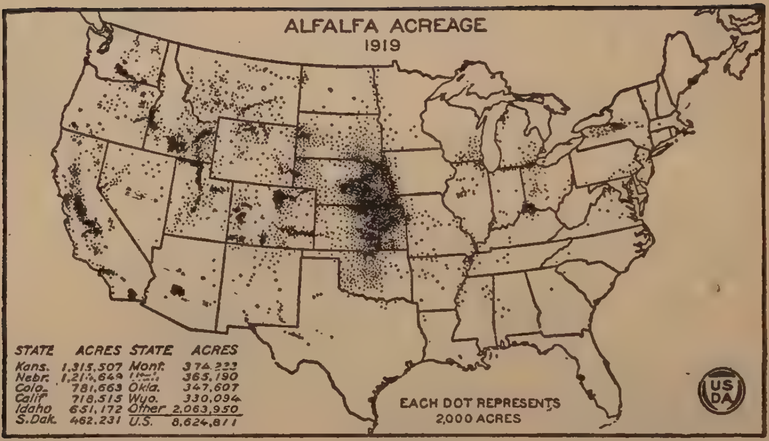
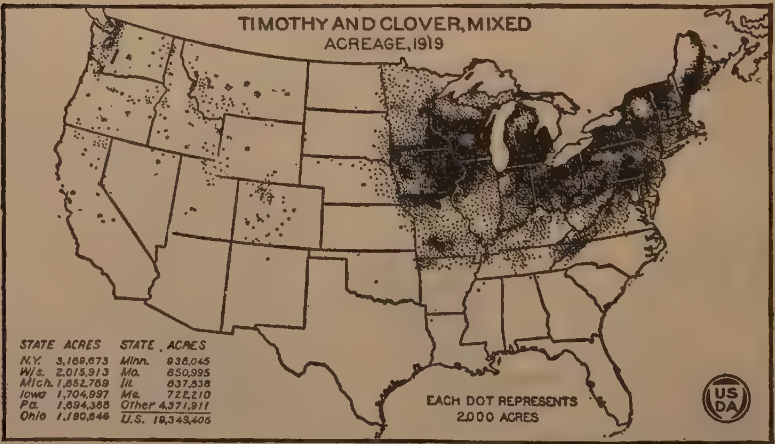

SORGHUMS HARVESTED FOR GRAIN, BUCKWHEAT, AND VELVET BEANS
Acreage, 1924
SORGHUMS FOR GRAIN
BUCKWHEAT
VELVET BEANS
UNITED STATES TOTAL
SORGHUMS FOR GRAIN 3,526,000 ACRES
VELVET BEANS 1,476,000 ACRES
BUCKWHEAT 717,000 ACRES
Each dot represents 2,000 acres
BASED ON THE CENSUS

Fig. 30.—Acres of grain sorghum, buckwheat and velvet beans in the United States, 1924. (U. S. Dept. Agr. Yearbook 1928, page 648.)


ALFALFA ACREAGE
1919
EACH DOT REPRESENTS
2,000 ACRES
US
DA

STATE	ACRES	STATE	ACRES
Kans.	1,315,507	Mont.	374,223
Nebr.	1,214,649	[illegible]	365,190
Colo.	781,663	Okla.	347,607
Calif.	718,515	Wyo.	330,094
Idaho	651,172	Other	2,063,950
S.Dak.	462,231	U.S.	8,624,811

Fig. 31.—Alfalfa acreage in the United States, 1919. (U. S. Dept. Agr. Yearbook 1923, page 345.)


TIMOTHY AND CLOVER, MIXED
ACREAGE, 1919
EACH DOT REPRESENTS
2,000 ACRES
US
DA

STATE	ACRES	STATE	ACRES
N.Y.	3,169,673	Minn.	938,045
Wis.	2,015,913	Mo.	850,995
Mich.	1,852,769	Ill.	837,838
Iowa	1,704,997	Me.	722,210
Pa.	1,694,368	Other	4,371,911
Ohio	1,190,646	U.S.	19,349,406

Fig. 32.—Acrcage of mized timothy and clover in the United States, 1919. (U. S. Dept. Agr. Yearbook 1923, page 347.)

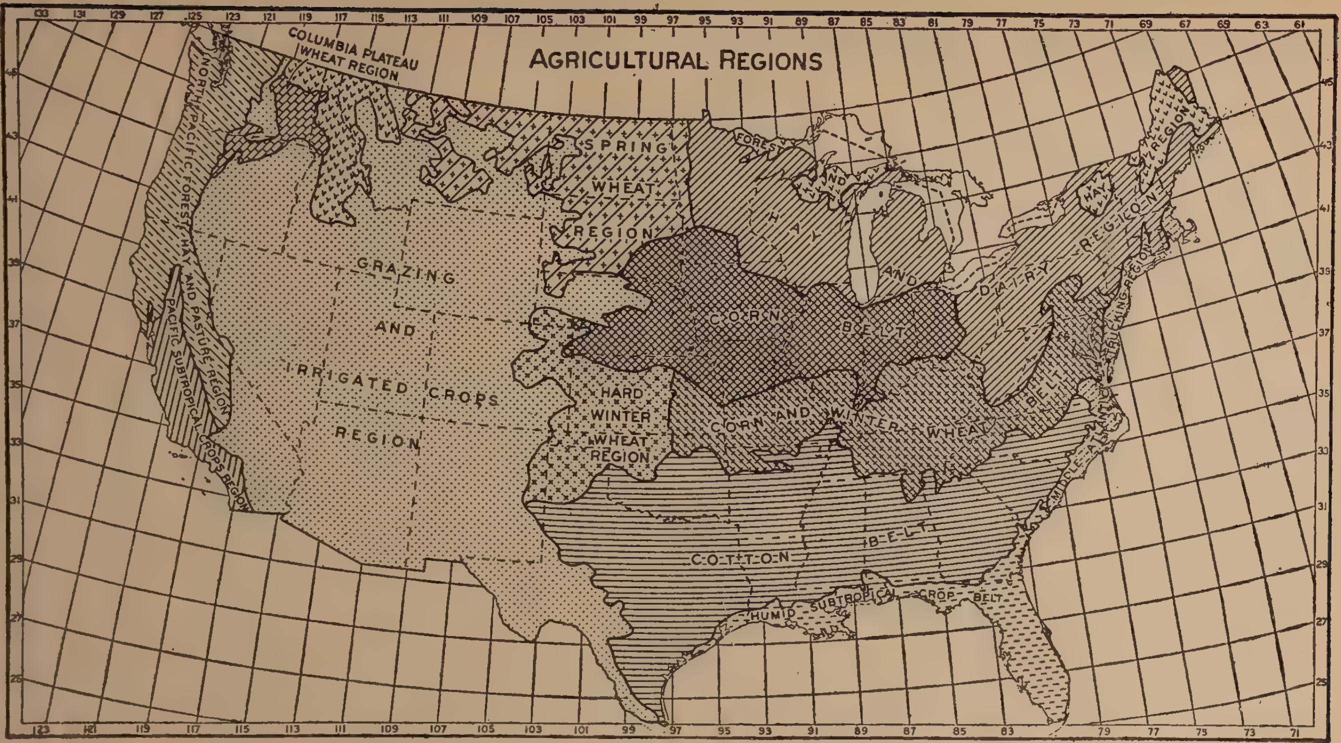

AGRICULTURAL REGIONS
COLUMBIA PLATEAU WHEAT REGION
NORTH PACIFIC FOREST, HAY AND PASTURE REGION
PACIFIC SUBTROPICAL CROPS REGION
SPRING WHEAT REGION
GRAZING AND IRRIGATED CROPS REGION
HARD WINTER WHEAT REGION
FOREST
AND
HAY
AND
DAIRY
REGION
CORN BELT
CORN AND WINTER WHEAT BELT
TRUCKING REGION
MIDDLE ATLANTIC
COTTON BELT
HUMID SUBTROPICAL CROP BELT
HAY

FIG. 33.—The great agricultural regions of the United States. (U. S. Dept. Agr. Yearbook 1928, page 641.)

STUDY QUESTIONS ON CHAPTER II

1. From a study of the figures and maps on the use of land in the United States, what would you conclude with reference to:
    - a. The possibilities of continuing to increase production by cropping new areas?
    - b. The possibility of a rising price level resulting in an increase in food supply?
    - c. The extent to which land not in harvested crops at present may be brought under cultivation in the relatively near future and the conditions which might be expected to bring this about?
2. Outline a tour for a foreign delegation through the great crop-producing areas of the United States.
3. Point out the ways in which variation in moisture (rainfall and humidity) may affect crop distribution.
4. In what ways do temperature and the length of the growing season affect crop distribution?
5. How do you account for the extent to which dairying is practiced in the northeastern section of the U. S.; general farming in the corn belt; grain farming in the wheat belt; and grazing in the foothills section and timbered regions of the west?
6. Prepare a chart listing the important crops; their major geographic distribution; the rainfall of the section best adapted to each crop; the length of the growing season and the temperature in the major area; the soil types in the major area if they are outstanding; the topography of the land, and miscellaneous economic factors which aid in accounting for the location of the crop areas.
7. Starting in the center of each of the following crop belts: corn, cotton, wheat, timothy and clover and oats, list the factors which tend to determine the limits of each area or belt.
8. Present a summary of the factors affecting crop distribution in your section of the country with a definite example or illustration of the working of these factors. There may be factors not mentioned in the text.
9. Give a summary statement of the variation in available moisture in the soil and outline an ideal condition with reference to the corn crop.
10. How has the maturing of crops at particular seasons ordinarily been accounted for? How would the length-of-day theory account for this?

APPLICATION ASSIGNMENTS ON CHAPTER II

1. Assume that you own five farms, located one each in North Dakota, Illinois, Oklahoma, Alabama and New York. Assuming that each represents an average farm in the state in which it is located, prepare an outline of each, showing the probable cropping plan and in a paragraph state why the particular crops are grown and the type of farming followed.

2. On your farm all tillable pasture land has been plowed up and you are growing as large an acreage of your highest cash crop as you can. You are filling out the remainder with second choice, high cash value crops. The price of agricultural products and the cost of labor and taxes suddenly go to twice the normal. What changes will you make?
3. You live in Wisconsin and are thinking of growing wheat. Will you grow winter or spring wheat? Why?
4. You live in Alabama. Cotton is your major crop. You wish a secondary crop which will fit in. You are thinking of corn, oats, and winter wheat. Which will you grow? Why?
5. You are employed to sell a machine which enables one man to prepare the seed bed as fast as two using the machines heretofore available. You have your choice of territory in the three great crop belts: corn, wheat, and cotton. Which territory will you take? Why?
6. You have recently purchased a farm in the cotton belt where the tillable land is all planted to cotton. Yields are maintained at a very high point by the use of commercial fertilizers. What rotation of crops will you adopt? Why?
7. A friend of yours in North Dakota sent you a bean to grow which matured satisfactorily in North Dakota. You grew this bean in Louisiana and were surprised that it made a trailing vine and did not mature at all. How would you explain this?

CHAPTER III

CHOICE OF CROPS

The choice of crops which each individual farmer must make is governed by somewhat the same general considerations in all parts of the country. Attention might well be given to (1) the different groups of crops—their classification, (2) the factors which influence the choice of crops to be grown, (3) the choice of crops grown in the past, and (4) the choice of crops grown under present conditions.

CLASSIFICATION OF CROPS

Crops are roughly classed as (1) cultivated or row crops such as corn, cotton, and tobacco, (2) non-cultivated annual crops such as oats, wheat, and barley, and (3) sod or hay crops such as clover, alfalfa, and timothy. They are also grouped according to their botanical character, their duration, and their use.

60. Botanical Classification of Crop Plants. All life may be divided into the plant and animal kingdoms. The higher forms of these two groups are differentiated readily, but it is extremely difficult to distinguish between some of the lower forms. In the plant kingdom, there are something over 230,000 different species and each species contains from one to many different varieties or strains. In order to classify these numerous different plants, the plant kingdom has been divided into four main divisions which are briefly described below.

I. *Thallophytes* are the simplest form of plants and are usually considered the most primitive. Most plants of this group are non-chlorophyll-bearing and possess little or no woody tissue. To this group belong the bacteria, fungi, and algæ.

II. *Bryophytes* are plants having better organized bodies than those of the *Thallophyte* group. Plants in this class are simple in structure, chlorophyll-bearing, and are sometimes differentiated into stems and leaves. They do not, however, possess true roots or bear flowers, and none are cultivated. The moss plants and liverworts belong to this group.

III. *Pteridophytes* are plants having true roots, stems, and leaves, but no flowers. There are about six thousand species in this group, most of which are tropical. They are propagated by means of spores but are considered higher forms of life than the plants in either Group

60a. *Botanical classification of crop plants.*

a—Monocotyledons

Common Name	Order	Family	Genus	Species	Subspecies
Pod corn	*Graminales*	*Gramineæ*	*Zea*	*mays*	*tunicata*
Flint corn	"	"	"	"	*indurata*
Dent corn	"	"	"	"	*indentata*
Sweet corn	"	"	"	"	*saccharata*
Flour corn	"	"	"	"	*amylacea*
Pop corn	"	"	"	"	*everta*
Common wheat	"	"	*Triticum*	*sativum*	*vulgare*
Durum wheat	"	"	"	"	*durum*
Club wheat	"	"	"	"	*compactum*
Polard wheat	"	"	"	"	*turgidum*
Spelt	"	"	"	"	*spelta*
Emmer	"	"	"	"	*dicoccum*
Polish wheat	"	"	"	*polonicum*	
Einkorn	"	"	"	*monococcum*	
Two-row barley	"	"	*Hordeum*	*distichon*	
Six-row barley	"	"	"	*vulgare*	
Rye	"	"	*Secale*	*cereale*	
Rice	"	"	*Oryza*	*sativa*	
Spreading oats	"	"	*Avena*	"	*sativa*
Side oats	"	"	"	"	*orientalis*
Hulless oats	"	"	"	"	*nuda*
Wild oats	"	"	"	*fatua*	
Red oats	"	"	"	*byzantina*	
Grain sorghums	"	"	*Andropogon*	*sorghum*	
Sweet sorghums	"	"	"	"	
Sudan Grass	"	"	"	"	
Johnson Grass	"	"	"	*halepensis*	
Sugar cane	"	"	*Saccharum*	*officinarum*	
Foxtail millet	"	"	*Setara*	*italica*	
Broom corn millet	"	"	*Panicum*	*miliaceum*	
Japanese millet	"	"	*Echinochloa*	*frumentacea*	
Pearl millet	"	"	*Pennisetum*	*glaucum*	
Timothy	"	"	*Phleum*	*pratense*	
Redtop	"	"	*Agrostis*	*alba*	
Quack grass	"	"	*Agropyron*	*repens*	

60a. *Botanical classification of crop plants.*—(Continued)

b—Dicotyledons

COMMON NAME	ORDER	FAMILY	GENUS	SPECIES	SUBSPECIES
Upland cotton	*Malvales*	*Malvaceae*	*Gossypium*	*hirsutum*	
Sea Island cotton	“	“	“	*barbadense*	
Potatoes	*Palemoniales*	*Solanaceae*	*Solanum*	*tuberosum*	
Tobacco	“	“	*Nicotiana*	*tabacum*	
Flax	*Geraniales*	*Linaceae*	*Linum*	*usitatissiumum*	
Hemp	*Urticales*	*Urticaceae*	*Cannabis*	*sativa*	
Sunflower	*Campanulales*	*Compositae*	*Helianthus*	*annus*	
Buckwheat	*Polygonales*	*Polygonaceae*	*Fagopyrum*	*esculentum*	
Rape	*Papaverales*	*Cruciferae*	*Brassica*	*napus*	
Sugar beet	*Chenopodiales*	*Chenopodiceae*	*Beta*	*vulgaris*	
Soybeans	*Rosales*	*Leguminosae*	*Soja*	*max*	
Field peas	“	“	*Pisum*	*arvense*	
Cowpeas	“	“	*Vigna*	*sinensis*	
Peanuts	“	“	*Arachis*	*hypogaea*	
Red clover	“	“	*Trifolium*	*pratense*	
White D. clover	“	“	“	*repens*	
Crimson clover	“	“	“	*incarnatum*	
Alsike clover	“	“	“	*hybridium*	
Biennial white sweet clover	“	“	*Melilotus*	*alba*	
Annual white sweet clover	“	“	“	*alba*	*annua*
Biennial yellow sweet clover	“	“	“	*officinalis*	
Annual yellow sweet clover	“	“	“	*indica*	
Alfalfa	“	“	*Medicago*	*sativa*	
Dalea	“	“	*Dalea*	*alopecuroides*	
Navy beans	“	“	*Phaseolus*	*vulgaris*	
Cherokee clover	“	“	*Desmodium*	*purpureum*	
Winter vetch	“	“	*Vicia*	*villosa*	
Spring vetch	“	“	“	*sativa*	
Lespedeza clover	“	“	*Lespedeza*	*striata*	
Velvet bean (Florida)	“	“	*Stizolobium*	*deeringianum*	

I or Group II. In this group are found the ferns, clubmosses, and scouring rushes.

IV. *Spermatophytes* are the seed-producing plants. Plants belonging to this group are considered the most highly organized in the vegetable kingdom. They have true roots, stems, leaves, and flowers. There are in this group about one hundred and thirty thousand species. The *spermatophyte* group is further divided into two divisions: the Gymnosperms, plants which do not have their ovules enclosed in an ovary wall, and the Angiosperms, plants having their ovules enclosed in an ovary wall. To the Gymnosperm division belong all coniferous or cone-bearing trees. To the division of Angiosperms belong all *broad-leaved trees*, the cereals and other common crop plants. The Angiosperms are divided into two classes: the monocotyledons and dicotyledons. All the grasses such as corn, wheat, and oats belong to the first group and all the legumes such as clover, alfalfa, and beans belong to the latter group. The classes are divided into orders, the orders into families, the families into tribes, the tribes into genera, the genera into species, and the species into varieties.

The outline in *60a* arranged by Ralph T. Stewart indicates the relation between some of the more common crop plants.

61. Duration as a Basis for Classification. Crops which last one season are called annuals. A winter annual may be seeded in the fall and will complete its growth the next season. Biennials continue for two seasons, while perennials continue for more than two seasons.

62. Use as a Basis for Classification. Crops are classified into cereal, grain, forage, fiber, sugar, root, and stimulant crops, depending upon the major purpose for which they are grown. A special purpose crop may be any of the other types grown for a specific purpose.

Cereal crops are grass crops grown for their edible seed. *Grain crops* include the cereals and other crops grown for their edible seed. *Forage crops* are grown for their vegetative parts and used as food for animals. *Fiber crops* are grown for their fibers which are used for textiles, ropes, twines, etc. *Sugar crops* are grown for their sugar content. *Stimulant* crops are grown for the particular stimulating properties they possess. Tobacco is an example of this class of crops.

Special purpose crops have a wide range of uses. Some of these are as follows: *Silage crops* are grown to be cut and preserved in a succulent condition. *Soiling crops* are cut and fed green. *Green manure* crops are grown to be plowed under for soil improvement. *Cover crops* are grown to protect the soil from wind, water erosion, and leaching. *Emergency* crops are any crops which may be grown in place of intended crops that have failed. *Nurse crops* are grown to utilize the land and at the same time protect seedling crops of clovers or grasses during their early growth. *Supplementary crops* are grown as secondary crops in combination with other crops to increase the yield or the feed value. *Companion crops* are grown as secondary crops to occupy a portion of the land at a time when it is not required by the principal crop in order to increase the total annual return. *Catch crops* are grown in gaps in the rotation.

Any crop may be used as a special purpose crop in one or more of the above groups, depending on the purpose for which it is grown and the use made of it.

FACTORS WHICH INFLUENCE THE CHOICE OF CROPS

63. Importance of Right Choice. Most farmers have the privilege each year of choosing the crops to be grown. In certain cases the landlord may determine the crop which will be grown, or the equipment or surroundings may limit the field so narrowly that there is practically no choice. The choosing of crops or enterprises as determined upon by the farmer corresponds to the merchant choosing the line of goods he will carry and the volume of the lines he thinks he can dispose of with reasonable promptness.

Probably most farmers are guided largely by what they have done in the past without giving much thought to what others are doing and the effect which this may have on the next season's return. The farmer may go on for a whole season and then find that both he and his neighbors have erred in judgment and have produced a crop for which there is little or no demand.

For the average farmer, perhaps, the safest guide is to do what every one else is doing. However, the keen-minded business man or farmer merchandises or produces a maximum of those commodities which are highly profitable, due either to their being new or to the fact that the natural swing of production or demand has left them higher than normal with reference to other commodities. The major crop of most sections is a high profit crop for that section. It is in the selection of secondary crops that a man has his best opportunity to improve on the average. The farmer is handicapped by the fact that the season may entirely change the outlook between planting time and harvest so that his selection, due perhaps to the production of bumper crops, may prove unwise.

Time and thought spent on the sensible choice of crops give a greater proportionate increase in return than can be hoped for from time spent on better methods of tillage or perhaps on other managerial functions. The crops selected must of necessity be adapted to the soil, the climate, the labor available; and also promise a relatively high value per unit.

The influence of climate, topography, fertility, land values, tenantry, transportation costs, and proximity of markets as influencing choice of crops in the end must be considered on the basis of the individual farm. The personal interest and enthusiasm of the grower in a particular crop is also a factor though this should not be allowed to outweigh those just enumerated.

64. Topography and Tillable Area. The per cent of land included in farms which can be planted to cultivated crops varies greatly in different sections of the country and marked differences are noted in different states and groups of states.

Large areas of rough land in pasture are found in the northeastern part of the United States and its effect on the choice of crops may be judged by comparing the crops grown in this area with those grown in the center of the corn belt or in the great plains where relatively much less of the land is not unsuited to the production of cultivated crops. It will be kept in mind, of course, that topography is only one factor influencing the choice of crops.

Rough land included in farms is that which cannot be used for harvested or cultivated crops and is shown by the pasture data in Table 66. The proportion of land in pasture per farm is also shown, together with the amount of land in pasture which can be used for the production of cultivated crops. The difference between these two figures indicates the untillable land area per farm. The extent of land not suitable for crops has a very definite relation to the type of farming that will be followed and to the crops which will be grown.

65. Land Value and Choice of Crops. The average value per acre of the plow land for each state is given in Table 66. The acre value of the land determines somewhat the relative intensity of the culture to be practiced. Land that is high in price must be made to produce crops with relatively higher values than can be grown satisfactorily on the cheaper lands. The state averages fail to show the close relationship that would be found if smaller areas were used. As an illustration of this, the area of relatively high land value in Iowa is found in a broad wedge-shaped area extending across Iowa from northwest and passing out with the narrow edge of the wedge just south of east central Iowa. The areas having a high per cent of land in pasture are in the sections of the state not covered by this wedge. Pasture land demands livestock for its utilization. If cattle are kept, the type, whether beef or dairy, depends somewhat on the land value—dairy animals usually, though not always, being found on the higher priced land.

66. Use of Land by States, U. S. Dept. Agr. Yearbook 1925.

	Total Land in Farms 000 Omitted	Area per Farm	Farmstead Waste; Lanes, etc.	Land in Pasture	Land in Pasture that Can Be Cropped	Area in Crops per Farm	Value per Acre of Plow Land	Per Cent Farms Operated by Tenants	Acres in Legumes per 100 Acres
Maine	5,165	103	5	35	4	33	$ 36	4.2	37.5
New Hampshire	2,262	107	5	52	4	26	41	6.7	29.1
Vermont	3,925	141	3	78	9	41	36	11.6	37.8
Massachusetts	2,368	71	5	26	3	20	70	7.1	18.3
Rhode Island	311	80	7	28	9	19	91	15.5	13.9
Connecticut	1,832	79	6	34	5	23	60	8.5	13.8
New England	15,862	99	5	43	5	29		8.9	25.2
New York	19,270	102	5	39	11	48	53	19.2	26.4
New Jersey	1,925	65	7	11	6	65	84	23.0	10.6
Pennsylvania	16,298	81	6	23	8	42	53	21.9	15.3
Middle Atlantic	37,493	90	6	29	9	45		21.4	17.4
Ohio	22,222	91	6	33	16	48	70	29.5	8.3
Indiana	19,918	102	7	29	14	61	74	32.0	6.4
Illinois	30,736	136	6	32	18	94	123	42.7	5.6
Michigan	18,037	94	9	30	9	50	57	17.7	18.7
Wisconsin	21,852	113	9	45	9	52	72	14.4	18.8
East North Central	112,764	107	7	34	13	62		22.7	11.5
Minnesota	30,041	160	12	42	11	99	73	24.7	5.1
Iowa	33,286	156	7	44	24	103	135	41.7	7.5
North Dakota	34,327	452	44	118	41	288	31	25.6	0.5
South Dakota	32,007	402	21	173	77	207	58	34.9	3.1
Missouri	32,637	125	6	51	26	59	63	28.8	5.0
Nebraska	42,024	329	13	152	34	162	90	42.9	5.9
Kansas	43,729	264	10	108	47	144	54	40.4	4.6
West North Central	248,051	223	12	82	32	125		34.1	4.5

Delaware	900	88	9	10	8	51	48	39.3	8.3
Maryland	4,440	91	8	18	11	45	50	28.9	8.8
District of Columbia..	4	27	5	4	2	17			
Virginia	17,213	89	5	27	15	28	42	25.6	8.0
West Virginia	8,984	99	6	47	19	21	38	16.2	6.3
North Carolina	18,598	66	7	10	3	24	52	43.5	5.8
South Carolina	10,644	62	8	9	2	29	38	64.5	5.6
Georgia	21,964	88	11	15	3	43	25	66.6	8.4
Florida	5,940	100	13	25	4	34	33	25.3	10.6
South Atlantic	88,687	80	8	18	7	31		38.6	7.7
Kentucky	19,915	77	7	30	21	26	44	33.4	3.3
Tennessee	17,911	71	6	19	10	30	46	41.1	7.1
Alabama	16,743	70	7	15	5	32	28	57.9	10.2
Mississippi	16,053	62	6	17	5	26	24	66.1	3.9
East South Central.	70,622	70	6	20	11	29		49.6	6.1
Arkansas	15,682	71	7	14	4	33	32	51.3	3.3
Louisiana	8,838	67	8	13	6	32	35	57.1	1.0
Oklahoma	30,934	157	8	66	20	80	38	51.0	2.1
Texas	109,798	236	7	162	32	63	50	53.3	1.0
West South Central.	165,252	162	7	92	20	56		53.2	1.8
Montana	30,740	698	28	484	88	181	19	11.3	5.0
Idaho	8,140	201	18	88	9	92	68	15.9	11.6
Wyoming	18,638	1,202	26	1,050	141	121	25	12.5	13.7
Colorado	24,168	416	24	264	88	124	48	23.0	14.5
New Mexico	27,928	881	58	761	169	57	38	12.2	17.0
Arizona	11,065	1,025	31	935	13	54	116	18.1	23.6
Utah	4,997	192	17	118	5	55	90	10.9	22.4
Nevada	4,192	1,071	148	785	21	136	78	9.4	18.4
Mountain	131,868	565	30	421	75	110		14.1	15.8
Washington	12,608	172	11	71	6	83	80	18.7	6.1
Oregon	14,120	253	10	157	11	76	78	18.8	7.6
California	27,565	202	13	124	22	62	111	21.4	11.0
Pacific	54,294	204	12	116	15	70		19.6	
United States	924,893	145	9	64	18	61	63	38.1	

67. Tenant Farming. The per cent of the land farmed by tenants in each state is shown in Table 66. The need for a change in the method of leasing farm land so that the tenant can afford to give attention to the maintenance of soil fertility has been recognized for years. With a short-time lease the tenant farmer can do very little to build up or maintain the soil. He is limited in his choice of crops to those crops which are short lived and give an immediate cash return.

In sections of the country where the farms are operated by owners, we expect a more far-sighted policy with reference to maintaining soil fertility. The section of the United States with the lowest per cent of tenancy is the northeastern states, the highest in the southern states. In both these sections, tenancy seems to be decreasing, while it is increasing in the western states and in the United States as a whole. For the census years 1880, 1890, 1900, 1910 and 1920 the per cent of the farms operated by tenants in the United States was 25.6, 28.4, 35.3, 37.0, and 38.1, respectively. In Iowa, the percentages for the same years in order were 23.8, 28.1, 34.9, 37.8, and 41.7.

Something of the attitude of tenants and owners toward the maintenance of soil fertility may be obtained from the figure showing the amount of legumes grown per 100 acres of improved land in 66. This shows the average by states. Certain sections of a state may be growing a much larger acreage of legumes than other sections of

FIG. 34.—Typical Iowa products. *Does Iowa produce its large number of hogs because of its corn crop or grow a large acreage of corn to supply feed for its hogs? Account for the fact that Iowa ranks first both in corn and hog production.*

the same state and this is not evident from the state averages. In northeast Iowa, the acreage of legumes per 100 acres of land in crops in 1919 was about twenty, while in southwest Iowa it was only two.

68. Labor Requirement of Crops. The requirement of a crop for labor at a particular time affects the choice of crops and the combinations a farmer will make in his cropping system. This is undoubtedly one of the important factors in choosing the crops which will be included in the rotation on a particular farm. Differences in the labor requirements and labor distribution for different crops are indicated in Table *68a*.

68a. Monthly distribution of man and horse labor in hours per month for important crops in representative states.[1]

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Sugar Beets (Colorado)												
Man	1.2	1.0	5.3	15.0	13.0	13.1	7.5	5.8	24.5	22.2	13.5	1.2
Horse	2.5	2.1	18.5	11.5	3.1	3.5	4.5	2.5	16.2	16.2	22.3	2.8
Alfalfa (Wisconsin)												
Man						7.2	5.0	2.9	2.6	0.1		
Horse						6.5	5.2	3.4	3.1	0.2		
Tobacco (Kentucky)												
Man	30.0	35.0	31.0	6.0	40.0	51.0	28.5	47.0	56.5	1.5	27.6	33.7
Horse	1.8	4.4	11.0	7.5	27.0	15.0	6.4	7.2	12.5	1.5	1.5	1.0
Oats (Illinois)												
Man			0.1	2.8	0.1	0.2	2.5	3.4	0.4			
Horse			0.1	9.6	0.2	0.1	3.9	4.9	0.4			
Barley (Wisconsin)												
Man				3.6	1.4		3.0	5.7	1.0	0.5	0.7	
Horse				10.3	3.7		4.0	5.7	0.5	0.2	0.4	
Fall Rye (Wisconsin)												
Man							4.2	4.4	1.8	2.0	0.3	
Horse							4.8	7.4	1.8	4.2	1.5	
Spring Wheat (North Dakota)												
Man				1.4	1.0	0.1		1.7	2.0	0.6		
Horse				5.6	3.8			3.1	2.6	1.1		
Corn (Illinois)												
Man				0.5	4.7	4.6	2.6	0.7	0.5	0.7	3.0	1.5
Horse				1.1	15.4	8.8	5.0	0.3	0.6	1.2	5.9	3.4
Cotton (Alabama)												
Man		6.0	4.8	5.0	9.3	12.3	11.0	4.2	7.5	8.3	2.5	3.0
Horse		9.7	15.0	6.8	10.4	7.2	6.1	1.8	1.8	0.9	1.0	0.1

69. Type of Labor and Crops. The seasonal distribution of labor is but one way in which the labor requirement of a crop may influence the grower in his crop choices. The type of the labor required is important as it affects other phases of life in the community as well as the choice of crops. A certain type of labor is used in the cotton belt, a radically different type in the wheat belt, and a still different type in the corn belt. Sugar beet, broom corn, and tobacco growers also have their particular labor problems.

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[1] Moorhouse, L. A., and Juve, O. A.—"Labor and Material Requirements of Field Crops." *U. S. Dept. Agr. Dept. Bul. 1000.* 1921.

In the old cotton belt labor is needed for chopping and hoeing the cotton through the first half of the season, then after a short period the picking season comes on for the fall months. This necessitates resident or family labor. Replacing either of these periods of labor with machinery might result in a serious labor scarcity for the other period of handwork. Importation of labor for this seasonal work is not satisfactory, as considerable skill is required. Cotton picking is not easily learned by adults. Children 10 to 12 years of age will pick more cotton in a given time than most adults not trained at this work. Likewise, speed and accuracy in using the hoe in thinning and hoeing is not readily acquired.

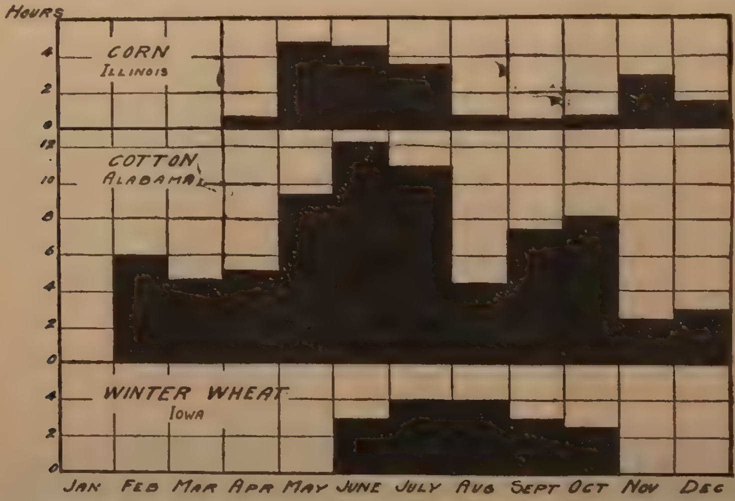

FIG. 35.—Man and horse labor required for representative crops by months. *Arrange in order of importance the factors most largely responsible for the choice of crops grown in southwest central Kansas; in central Illinois.*

In the wheat belt, the rush work comes at harvest time. The period of harvest is relatively short and, therefore, transient labor is required. This type of labor is perhaps the most unsatisfactory of all from the standpoint of dependability. The wheat grower is never certain that he will be able to secure sufficient help, nor that it will stay with him until harvest is completed. This unsatisfactory situation has induced the wildest enthusiasm for machinery to replace this labor and much progress has been made in this direction.

Another type of labor is found in the corn belt. Skill is not required as in the cotton belt, for a green hand may soon learn to do good work. The hired laborer has a job for the season and becomes almost one of the family. This type of laborer is usually rather satisfactory and no such effort has been made to replace him with machinery as in the case of the wheat farmer, though two and three row corn plows and corn pickers are being used more and more commonly in an effort to increase the return per unit of labor. In growing corn skill in handling a team in cultivating the crop is of the greatest importance.

In the sugar beet sections and at harvest time in the broom corn sections, labor is brought in for the particular pieces of work. A hired family usually takes charge of the thinning, weeding, and topping of a certain number of acres of beets. This family in many cases is given a temporary building on the farm, leaving when they have finished the season's work. Broom corn requires a large amount of especially trained labor for a very short harvest period.

Fig. 36.—A typical Iowa farmstead. *Is one ever justified in allowing the buildings and equipment available to determine the crops produced?*

70. Cash Value of the Crop. One of the greatest factors affecting the choice of crops is the acre value. The average value of a crop for a given section is found by multiplying the average yield by the average price per unit. Table *70a* gives the gross acre values of the crops important in different sections of the country. These figures are not directly comparable as the cost of producing and harvesting the different crops varies greatly. The yields are averages for the years 1921-1924, inclusive, and the prices are the average farm prices for the same years in so far as they could be obtained.

70a. Acre values of field crops by states, based on average

	Corn	Winter Wheat	Spring Wheat	Oats	Barley	Rye	Alfalfa
Maine	45	—	37	15	27	—	—
New Hampshire	45	—	—	24	26	—	64
Vermont	45	—	27	22	27	—	50
Massachusetts	46	—	—	21	—	27	79
Rhode Island	50	—	—	19	—	—	—
Connecticut	47	—	—	19	—	27	78
New York	34	23	19	17	20	16	40
New Jersey	34	24	—	15	—	18	53
Pennsylvania	35	20	18	17	17	16	43
Ohio	26	18	16	14	17	15	33
Indiana	21	17	16	11	13	11	32
Illinois	23	18	18	13	16	13	37
Michigan	28	20	16	13	16	11	29
Wisconsin	28	20	17	15	18	12	37
Minnesota	20	17	16	12	13	13	27
Iowa	23	21	14	12	15	14	31
Missouri	20	13	14	10	18	11	26
North Dakota	15	—	11	8	9	8	16
South Dakota	15	15	11	10	10	10	16
Nebraska	16	14	11	9	11	9	22
Kansas	13	13	9	9	9	9	22
Delaware	24	17	—	15	—	15	50
Maryland	29	19	—	16	26	16	46
Virginia	24	15	—	14	22	12	38
West Virginia	31	16	—	15	—	12	43
North Carolina	20	14	—	15	—	16	47
South Carolina	14	18	—	19	—	21	40
Georgia	12	15	—	15	—	16	38
Florida	12	—	—	10	—	—	—
Kentucky	21	13	—	12	21	12	35
Tennessee	20	13	—	12	21	12	40
Alabama	13	16	—	14	—	15	27
Mississippi	14	19	—	14	—	—	33
Louisiana	15	—	—	16	—	—	34
Texas	18	13	—	14	15	13	32
Oklahoma	17	12	—	10	13	10	23
Arkansas	16	13	—	13	—	12	30
Montana	16	15	13	12	14	8	20
Wyoming	15	14	14	14	19	10	18
Colorado	10	12	15	13	13	7	23
New Mexico	17	12	17	13	14	11	41
Arizona	34	33	—	24	29	—	62
Utah	25	16	26	20	24	9	25
Nevada	30	28	31	27	36	—	36
Idaho	30	37	23	18	22	13	28
Washington	38	22	14	24	22	10	46
Oregon	31	22	15	16	29	12	39
California	37	22	—	19	20	—	58

acre-yields and farm prices for the years 1921-1924.

TIMOTHY AND CLOVER	BUCK-WHEAT	COTTON	TOBACCO	FLAX	SUGAR BEETS	RICE	BROOM CORN
18	26	—	—	—	—	—	—
27	24	—	—	—	—	—	—
25	21	—	—	—	—	—	—
38	25	—	465	—	—	—	—
38	—	—	—	—	—	—	—
40	22	—	520	—	—	—	—
21	20	—	288	—	—	—	—
29	23	—	—	—	—	—	—
24	19	—	233	—	—	—	—
18	19	—	144	—	65	—	—
18	17	—	139	—	—	—	—
18	16	—	—	—	—	—	45
16	13	—	—	—	64	—	—
22	13	—	157	23	66	—	—
16	12	—	—	21	—	—	—
16	14	—	—	19	—	—	—
13	17	59	250	—	—	—	35
11	—	—	—	16	—	—	—
10	11	—	—	16	—	—	—
15	14	—	—	16	90	—	—
14	—	—	—	13	—	—	18
				PEANUTS			
25	15	—	—	—	—	—	—
26	19	—	174	—	—	—	—
21	18	56	144	54	—	—	—
24	19	—	181	—	—	—	—
27	20	59	153	70	—	—	—
23	—	36	107	50	—	28	—
22	—	25	172	34	—	26	—
—	—	20	425	40	—	30	—
21	17	—	146	—	—	—	—
23	18	40	139	54	—	—	—
21	—	30	—	27	—	—	—
18	—	34	—	33	—	20	—
18	—	29	237	54	—	37	—
18	—	30	—	34	—	40	25
16	—	28	—	37	—	—	18
16	—	35	—	40	—	49	—
16	—	—	—	14	—	—	—
13	—	—	—	14	—	—	—
17	—	—	—	—	89	—	14
25	—	—	—	—	—	—	13
23	—	74	—	—	—	—	—
17	—	—	—	—	92	—	—
20	—	—	—	—	—	—	—
17	—	—	—	—	86	—	—
29	—	—	—	—	—	—	—
25	—	—	—	—	—	—	—
24	—	62	—	—	90	67	—

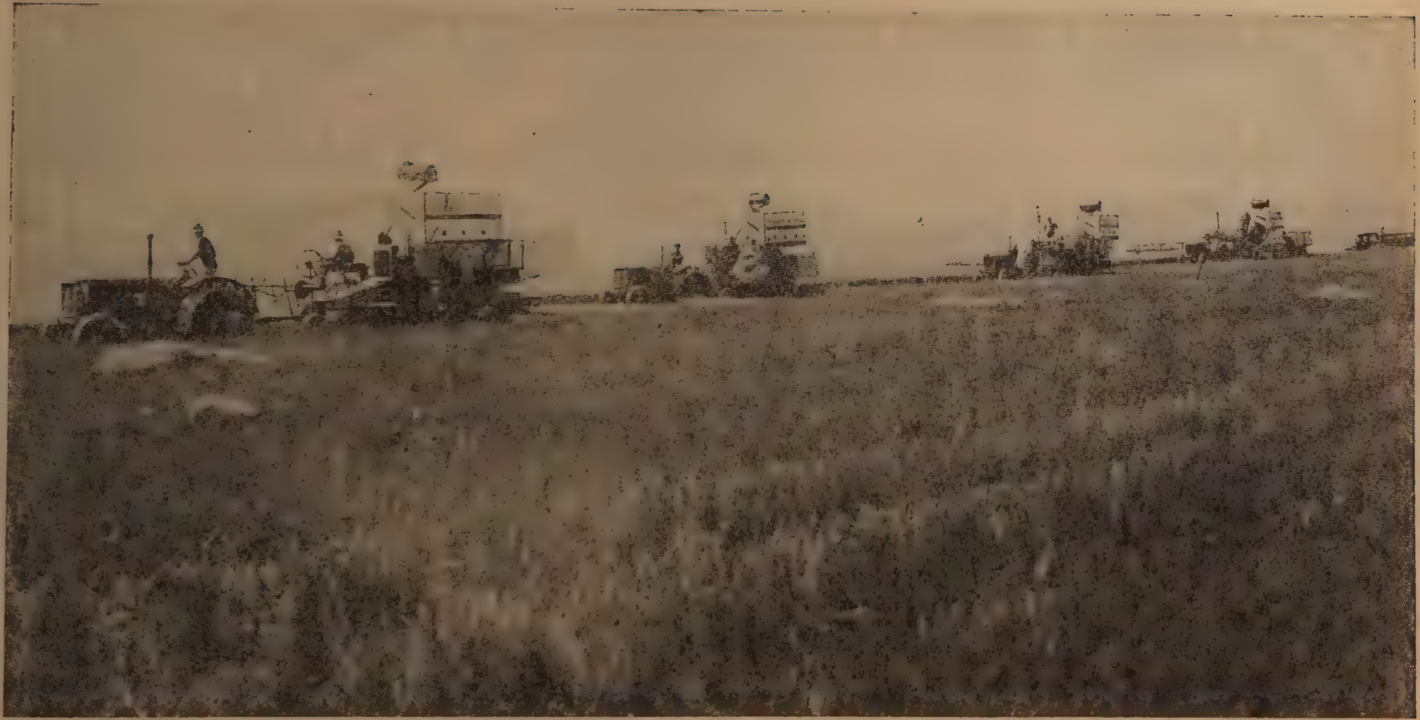

FIG. 37.—Harvesting wheat in Kansas. *Why has the demand for improved methods of harvesting wheat been so much more persistent than for other crops?*

71. Other Factors Affecting the Choice of Crops. Such factors as soil erosion, soil fertility, acidity, alkalinity, soil tilth, and similar conditions have a direct effect on the choice of crops. The type of livestock kept and the tendency of the community toward a particular type of farming may also have an important influence.

THE CHOICE OF CROPS IN THE PAST

72. Trends in Choice of Crops. When a new country is opened for settlement the crops chosen are usually those which have a high cash value and are capable of concentration so that they may be readily marketed without too great an expense for transportation. Under such conditions crops must be grown which do not demand excessive amounts of machinery. Flax is called a pioneer crop and perhaps wheat would also fall in this class. In a particular section the tendency is for a farmer to grow as many acres of his chief cash crop as he can tend and to fill in with crops that do not interfere with the main crop for labor. The advent of new crops or new areas adapted to an old crop may upset the entire cropping system of a locality. The discovery that the cotton plant would grow and do well in certain dry areas of Texas and Oklahoma threatens to require radical adjustments of cropping systems not only in that area but also in the old cotton belt. The acreage of the more important crops grown in representative states for a period of years is shown in

FIG. 38.—A first prize sample of seed corn at the North Dakota State Corn Show, 1927. *The acreage of corn is increasing rapidly in North Dakota. Are farmers in that state wise in turning to this crop? Explain.*

Table 73, as illustrating trends in the choice of crops in these different sections of the country. The five-year average just prior to the war is given for comparison with the present choice.

73. Acreage of field crops (000 omitted) in representative states for a period of years. U. S. Dept. Agr. Yearbooks.

	1862	1870	1880	1890	1900	1910-1914	1920	1922	1924	1926
Iowa										
Corn	1298	2919	6847	8771	8049	9913	10300	10364	10884	11170
Winter wheat ..							458	703	396	342
Spring wheat ...	753	1636	3190	1685	1397	345	400	68	32	36
Barley	19	47	171		444	448	180	161	150	268
Rye	5	29	103		100	43	32	55	48	31
Oats	181	550	1513		3840	3896	5894	5847	5775	6218
Flax						14	11	8	8	15
Timothy & clover							1306	1353	1792	1433
Alfalfa							180	192	276	272
Buckwheat	10	9	15		10	7	6	5	6	5
New York										
Corn	688	571	802	643	539	529	767	798	743	670
Winter wheat ..				641	123	314	467	456	380	270
Spring wheat ...	723	662	788				40	21	14	9
Barley	168	312	352		171	78	170	158	230	179
Rye	283	172	230		211	139	71	55	55	25
Oats	1256	915	1312		1596	1279	1059	1059	946	1017
Timothy & clover							2286	2248	2251	2205
Alfalfa							132	155	172	218
Buckwheat	51	17	21		9	18	26	208	222	190
Alabama										
Corn		2019	1829	2489	2669	3093	3593	3636	3245	2825
Winter wheat ..		124	260	293	96	50	70	25	11	7
Oats		45	318		304	308	246	277	197	107
Rye		6	6			1	1	1	1	. .
Alfalfa							10	20	23	25
Cotton			2461	2883		3805	2858	2771	3055	3651
Timothy & clover							2	3	3	. .
North Dakota										
Corn					24	341	569	780	1137	1009
Barley					244	1188	1085	1008	1350	1472
Spring wheat ...						7831	7600	8740	8685	9653
Oats					612	2243	2518	2388	2746	2024
Rye					16	71	974	1800	990	1222
Flax						1178	761	521	1873	1380
Alfalfa							56	65	120	143
Timothy & clover							19	18	18	27

CHOICE OF CROPS UNDER PRESENT CONDITIONS

74. Per Cent of Land in Crops by States. The more recent choice of crops is shown in Table *74a*. This table gives the per cent of the land in farms that is devoted to each of the important field crops, arranged by states. The figures are taken from the census data and the classifications are overlapping in some cases. For example, the per cent of the land in tame hay includes alfalfa and the other tame hays so that the percentages do not total 100 in all cases. These figures serve to indicate the use being made of the land and when studied in connection with figures showing the acre value of each crop and the labor requirement (Tables *70a* and *68a*) a rather definite idea of the farming practices and types in each state may be obtained.

STUDY QUESTIONS ON CHAPTER III

1. Criticize the statement that the choice of crops which a farmer may make correspond to a merchant's selection of the lines of stock which he will carry.
2. What effect does the presence of a large amount of rough pasture land have on a farmer's choice of crops? Illustrate.
3. Illustrate the general effect of high land value and nearness to market on the choice of crops for a particular farm.
4. How does tenancy influence the choice of crops?
5. Why does the corn belt grow such a large acreage of oats when the available data show that this crop returns very little profit?
6. If you were to make a trip through the cotton, corn and wheat belts, judging progressiveness, what would you look for?
7. How do the amount and kind of labor required above that of the operator and his family vary with the section of the country and the type of farming?
8. Rank in order of acreage the crops grown in your section and account for this selection.
9. Modify the list of crops grown in your section by substituting, wherever possible, other high cash value crops adapted to your conditions.
10. Account for the marked changes which have occurred over a period of years, in the relative importance of different crops, in different parts of the country.
11. From the acreage data of crops grown, indicate by a diagram the rotation most generally followed on a composite 160-acre farm in the hay and pasture region; in the corn belt; in the cotton belt; in the winter wheat belt, and in the spring wheat belt.

APPLICATION ASSIGNMENTS ON CHAPTER III

1. You are an average farmer and have purchased an average farm in the corn belt where all your neighbors grow large acreages of corn. You are debating whether or not you should grow corn or some other crop not so generally produced. What will you do? Why?
2. You have a farm in the wheat belt equipped for growing wheat. You note that prices are rather low and indications are that they will remain so low that you cannot expect to more than break even. Will you grow wheat? Why? Would the same be true of cotton in the cotton belt? Of a minor crop?

74a. Per cent of the crop land in various crops

	CORN	WHEAT	OATS	BARLEY	RYE	COTTON	FLAX	TOBACCO
Maine	.9	.25	6.2	.2	—	—	—	—
New Hampshire	3.8	—	2.6	—	—	—	—	—
Vermont	5.3	.2	4.6	.5	—	—	—	—
Massachusetts	6.8	—	1.0	—	.3	—	—	1.0
Rhode Island	9.0	—	—	—	—	—	—	—
Connecticut	10.8	—	.1	—	.02	—	—	4.0
New York	5.8	3.2	7.7	1.5	.4	—	—	—
New Jersey	15.0	4.8	4.4	—	4.1	—	—	—
Pennsylvania	13.1	10.8	9.5	.1	1.8	—	—	.4
Ohio	20.4	12.8	8.2	.4	.5	—	—	.2
Indiana	28.7	11.6	10.2	.2	1.8	—	—	.1
Illinois	33.0	11.1	14.4	.8	.8	—	—	—
Michigan	13.1	7.5	11.9	1.1	3.8	—	—	—
Wisconsin	17.9	1.0	20.3	3.6	3.1	—	.1	.3
Minnesota	19.8	8.6	19.7	4.3	4.2	—	2.4	—
Iowa	37.3	2.2	20.3	.5	.2	—	—	—
Missouri	26.0	10.5	5.5	—	.1	1.3	—	—
North Dakota	3.7	37.1	10.2	4.9	5.6	—	4.5	—
South Dakota	23.1	20.4	13.5	4.7	1.9	—	1.7	—
Nebraska	37.4	14.9	10.5	1.2	.7	—	—	—
Kansas	18.0	29.9	4.8	2.9	.2	—	.1	—
Delaware	28.0	16.1	1.1	—	.9	—	—	—
Maryland	20.0	18.3	1.9	.1	.6	—	—	.9
Virginia	19.5	8.5	1.8	.1	.4	.8	—	2.2
West Virginia	10.6	4.0	3.5	—	.2	—	—	.2
North Carolina	31.1	6.5	3.2	—	.8	20.3	—	6.5
South Carolina	32.0	2.5	6.5	—	.1	33.0	—	1.5
Georgia	32.0	1.2	3.1	—	.1	25.6	—	.2
Florida	35.4	—	1.5	—	—	5.0	—	—
Kentucky	23.1	4.1	1.6	—	.1	—	—	3.8
Tennessee	28.2	3.7	2.0	.1	.2	9.4	—	1.2
Alabama	33.8	.1	2.5	—	—	30.1	—	—
Mississippi	27.3	—	1.3	—	—	32.8	—	—
Louisiana	29.4	—	1.0	—	—	24.3	—	—
Texas	16.4	4.5	4.6	.3	—	45.1	—	—
Oklahoma	17.8	18.6	7.6	.8	.2	18.2	—	—
Arkansas	23.3	.7	2.9	—	—	32.5	—	—
Montana	3.3	30.4	6.1	1.0	1.6	—	1.4	—
Wyoming	6.8	7.8	7.8	1.2	1.3	—	—	—
Colorado	18.1	19.3	2.9	3.6	1.1	—	—	—
New Mexico	12.9	7.3	3.4	.1	—	—	—	—
Arizona	4.8	5.8	2.8	4.5	—	19.2	—	—
Utah	1.7	15.9	4.7	1.2	.6	—	—	—
Nevada	—	3.4	.5	.8	—	—	—	—
Idaho	1.5	23.0	3.8	2.1	.3	—	—	—
Washington	1.0	33.4	2.9	1.3	3	—	—	—
Oregon	1.4	22.4	5.5	1.8	.7	—	—	—
California	1.0	5.0	1.1	7.7	—	2.0	—	—
United States	20.7	11.7	8.2	1.5	1.1	7.3	.4	.4

by states. Three-year average—1921, 1922, 1923.[a]

RICE	SUGAR BEETS	TAME HAY	WILD HAY	AL-FALFA	CLOVER HAY	CLOVER AND TIMOTHY	TIMO-THY	ANNUAL LEGUME HAY	PASTURE [a]
—	—	62.8	.8	—	1.9	30.25	7.3	.01	33.7
—	—	63.6	1.7	—	2.0	25.0	8.8	.3	48.0
—	—	53.7	.8	—	1.5	32.8	6.2	—	55.4
—	—	47.2	1.3	—	1.5	16.1	7.8	—	37.0
—	—	33.8	—	—	—	12.0	6.0	—	35.8
—	—	45.6	1.3	—	2.0	11.8	6.1	—	42.7
—	—	37.3	.5	—	1.2	17.2	9.9	.04	38.4
—	—	20.1	1.4	1.3	2.1	8.9	4.9	.2	17.4
—	—	24.7	.2	.3	2.5	13.1	1.9	.03	28.1
—	.2	17.9	—	.7	4.3	5.1	7.2	.2	36.6
—	—	14.2	.1	.6	3.2	3.7	4.5	.5	28.5
—	—	12.9	.2	.5	3.4	2.8	3.7	.9	23.6
—	1.1	24.2	.4	2.7	6.0	9.2	5.2	.2	31.7
—	.2	25.6	2.7	1.4	5.7	12.5	4.9	.3	39.6
—	—	9.4	9.2	.7	1.8	3.3	2.6	.1	26.2
—	—	11.3	1.2	.8	3.0	4.5	2.6	—	28.4
—	—	13.8	.5	.7	2.6	4.2	4.7	.7	40.7
—	—	4.0	9.1	.4	.5	.1	.6	.1	26.0
—	—	5.7	18.7	3.2	.3	.5	.7	.1	43.1
—	.3	6.8	9.7	5.1	.5	.3	.1	—	46.3
—	—	5.3	3.0	2.9	.4	.3	.3	—	40.8
—	—	11.8	—	—	2.9	4.0	1.7	2.9	11.2
—	—	12.9	—	.5	3.2	4.7	2.6	1.0	20.1
—	—	10.7	.2	.3	1.9	3.4	1.1	2.4	30.7
—	—	13.8	.2	.1	1.4	5.2	5.2	4.2	47.7
—	—	9.4	1.2	—	1.3	.5	3.0	1.1	51.5
.1	—	7.1	.1	—	—	—	—	5.4	15.3
—	—	5.8	.1	—	—	—	—	2.7	17.3
—	—	5.6	—	—	—	—	—	2.4	25.4
—	—	8.0	.2	.4	1.3	1.5	1.6	.7	38.9
—	—	12.4	.5	.2	2.8	1.9	.9	2.8	26.2
—	—	8.0	.2	.2	.4	—	—	4.2	21.1
—	—	5.0	.4	.2	1.0	—	—	2.2	26.8
9.2	—	3.8	.3	.3	.7	—	—	1.9	19.3
.5	—	2.3	.7	.2	—	—	—	.2	68.7
—	—	5.3	2.9	2.0	—	—	—	.2	42.3
1.6	—	6.2	1.4	.8	.7	.6	.2	1.4	19.5
—	—	10.7	5.9	5.0	.6	1.3	.7	—	69.4
—	—	34.6	15.0	23.3	1.3	1.7	2.4	—	87.3
—	2.5	15.7	4.6	10.3	.3	1.5	.6	.2	63.3
—	—	9.0	2.3	15.8	—	—	—	—	86.3
—	—	22.9	1.1	18.9	—	—	—	—	91.2
—	5.1	30.4	6.2	26.4	—	1.6	.7	—	61.2
—	—	30.3	26.6	20.8	—	2.2	1.2	—	73.2
—	1.0	23.0	2.8	14.2	.7	2.1	2.2	—	43.9
—	—	14.3	.4	3.2	1.0	1.3	.7	—	41.2
—	—	19.9	4.4	4.9	2.9	.6	.4	1.0	62.2
.9	.6	17.5	1.1	8.9	.1	.4	.1	.2	61.3
.2	.2	12.1	3.0	2.0	1.7	3.1	2.2	.8	44.1

[a] Pasture figures are for 1924 and are per cent of total farm land in pasture.

3. You own a farm on which you have been practicing general farming. Land values have doubled suddenly, due to the extension of a city near you. Will you probably continue general farming?
4. You live in the corn belt but are thinking of planting 10 acres of broom corn, as you have noted that the price is $175 per ton. Will you grow it? What considerations are the deciding ones?
5. In order to help you make your college expenses your father rents to you a farm of 100 acres of average land for one year, telling you to make the highest cash income from it that you can. The farm has the usual pasture land. Draw an assumed plan of the farm, indicating the crops you propose to plant in each field.
6. After farming the above farm for one year, you decide to continue and you buy the farm. What changes will you make in your crop acreages? Why?

CHAPTER IV

HOW PLANTS GROW

While many plant growth processes are not well understood, much is known today regarding factors influencing plant growth which only a few years ago was shrouded in mystery. There is no other phase of crop production to which greater attention should be given than to the physiology of the plant and the response of the plant to its environment or to different treatments.

PLANT STRUCTURES

75. Cell Structure. Each part of the plant is made up of minute cells, each cell consisting essentially of a mass of protoplasm, the living matter of the plant, confined by the cell wall. Protoplasm is a fluid substance varying in density, and analysis shows it to be principally protein.

The protoplasm has special structures for definite functions. The nucleus, usually located near the center of the cell, is one of these structures. It consists of a compact mass of protoplasm enclosed in a membrane. Within the membrane is the nuclear sap consisting of water and dissolved substances. Chromatin, also found in the nucleus, is a granular substance which gathers into thread-like masses, breaking up into segments called chromosomes when cell division is about to take place. For each type of plant the chromatin gathers into a definite number of chromosomes. The inheritance of the plant is determined by these chromosomes.

The protoplasm outside the nuclear membrane is called the cytoplasm. It has cavities or vacuoles filled with cell sap and dense bodies of protoplasm called plastids. These plastids often carry pigments which give characteristic colors. The green pigments are chlorophyl. Plastids sometimes are colorless or carry other colors as found in the petals of flowers or in the stems or roots. Starch grains, oil drops, and other food substances are also found in the cytoplasm, the starch grains normally being within the plastids.

76. The Cell Wall. The cell wall is made of cellulose with secondary deposits of other material, in certain cases, for protection or greater strength. The shape of the cell is determined by its location in the plant and the special functions it has to perform. Cells of the leaves are more or less regular, while those making up the fibrovascular bundles are usually much elongated. The end walls of these long cells may be absorbed so that they join with those above and below to make a tube-like structure. The xylem or wood cells of the fibrovascular bundles use up their protoplasmic content in the building of the cell walls. In order to withstand the turgor pressure of the living cells about them, the walls of the xylem are reënforced with bands and spirals of lignin. Beside adding strength, these secondary thickenings may aid in water movement to the leaves. In most tissues there are spaces or cavities between the cells which may be connected with the outer air through the stomata.

Cell walls permit water and dissolved substances to pass through into the cell. Most substances which dissolve in water can readily pass through the cell walls, and harmful salts may get into the cell in this way. A narrower selection is made by the protoplasmic membrane which surrounds the cytoplasm next to the cell wall. Recent work indicates that most substances are absorbed as ions rather than as compounds. When a substance goes into solution, it becomes ionized. For example: sodium chloride becomes Na ions and Cl ions which may be absorbed in unequal proportions, thus leaving one or the other ion free to combine with ions from other solutes. In all cases there must be an exchange, as ions though separated in solution cannot be widely separated unless some other ion replaces it in its former relationships.

In this connection Hoagland[1] finds that different ions are absorbed by the plant at different rates and that one ion influences the absorption of another; as, an abundance of one ion, K, for example, may repress or stimulate the absorption by the plant of the ion containing P or N from other compounds. As the plant absorbs water and ions the same soil solution may become more dilute with respect to certain ions and more concentrated with respect to others.

In the older portions of the plant, the outer cells of roots, stems, and leaves excrete a waxy substance or form a layer of corky tissue, which renders the cell practically impermeable to water. Very little rain water is absorbed through the walls of the outer layer of cells above ground. The root hairs are the principal points of entry for water below the surface of the soil. The outer layer of cells of the older roots are suberized, or cutinized, so that water can scarcely penetrate at all, and also, of course, so that water which has been taken up by the root hairs cannot escape while it is moving upward to the leaves.

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[1] **Hoagland, D. R.—"The Absorption of Ions by the Plant."** ***Soil Sci.*** **Vol. 16, No. 4, p. 245. 1923.**

77. Leaves. Each flowering plant has leaves. These are usually broad, thin structures. They consist essentially of layers of chlorophyl-bearing cells interwoven with vascular tubes, called veins. These tubes serve as channels for the distribution of water and dissolved substances and for removing a part of the food which is manufactured in the leaf for the use of the remainder of the plant. The extent of the leaf area, its size and general form, is influenced somewhat by the environment. The leaves are so constructed and so displayed in each species that the optimum amount of sunlight tends to be absorbed. The leaf is the seat of manufacture of the carbohydrates through a process made possible with the aid of light and called "photosynthesis." Proteins may also be manufactured in the leaves by combining the sugars produced by photosynthesis with nitrogen and minerals from the soil. Light is not necessary for this process.

78. Stomata. The stomata are openings in the outer layer of cells, usually with two guard cells so shaped that when turgid or full of water the stomata are open, but when the guard cells wilt or lose water faster than it can be obtained from neighboring cells or vascular tissue they become flabby and the openings practically close. This checks evaporation from wilting leaves and prevents more serious injury by drying. Since the thick-walled guard cells are the last to wilt in sunlight, this closing does not regulate transpiration but simply serves to prevent excessive drying of the tender leaf cells. The guard cells respond quickly to light by opening in the morning and then closing at night when photosynthesis is impossible.

The stomata are connected with air spaces between the cells and permit gases, particularly carbon dioxide and oxygen, to diffuse into the atmosphere and from the atmosphere into the plant. The number and size of stomata vary with the plant and with the location on the upper or lower surface of the leaf. Certain environmental or growing conditions have been known to influence the number of stomata.

79. Flowers, Fruits, and Seed. Flowers, fruits, and seed are primarily for purposes of reproduction. The flower may be showy if it depends on insects for pollination, or it may be inconspicuous as are those of most of the grasses which are either self-pollinated or are cross-pollinated by the wind.

Flowers, whether conspicuous or not, consist essentially of the organs of reproduction. The pistil is the female organ and consists of stigma, style, and ovary. The ovary contains the ovule or ovules. Within each ovule of most crop plants there are two nuclei ready to fuse with the pollen sperms. One of these fusions produces the endosperm or food storage tissues, while the other produces the new plant or embryo of the seed. The stamens are the male organs and each consists of a filament and an anther. The anther sheds the pollen which is carried to or falls on the stigma, where it germinates and sends a tube down to an ovule. Male cells pass down behind the growing tip of these tubes and fuse with the nucleus of the egg cell.

Food materials, manufactured in the leaves, may be stored in the endosperm or in the cotyledons of the embryo. These food materials are transported in a soluble form through the phloëm to the points where they are being used or stored. Storage of foods is brought about through a transformation by enzyme action which renders the substances insoluble. For example, sugars may be changed to starch. When conditions are right, these materials are again acted on by enzymes and changed back to the soluble form. In many cases these latter enzymes are secreted in connection with the germination process.

80. Stems. The stems of plants support and display the fruits and leaves so that carbon dioxide and sunlight may be absorbed. Stems also support the flowers so that they may be well pollinated and protect and distribute the fruit and seed. The stems contain the transporting vascular bundles which serve to conduct the water and dissolved substances to the leaves and permit the transfer of plant foods to all parts of the plants. They may also serve as storage organs for accumulated foods. Young green stems carry on some photosynthesis.

Stems of plants differ in some respects in the arrangement of their parts. In monocotyledons, such as all grasses, there is on the outside a rindlike portion surrounding the light pith in the center. Scattered through the pith and increasing in number toward the outer rind are found the vascular bundles or conducting tissues. The number of bundles is determined at the growing point and does not increase as the stem grows older. Each bundle is made up of strengthening tissue and conductive tissue. The conductive tissue consists, in part, of xylem or trachea-like tubes made of elongated cells without protoplasm and in many cases with the end walls lacking. These tubes carry water up the stem but will allow diffusion into the surrounding tissue. The phloëm consists of sieve tubes and companion cells and is found in each bundle. The sieve tubes are living cells which have openings in the ends through which the protoplasm of the cells is connected. This arrangement is thought by many to be important in the movement of dissolved substances, since these can move from one cell to the next without passing through the almost impermeable plasma membrane.

The stems of dicotyledons, such as alfalfa, clover, and beans, have the phloëm in the soft outer zone, while the xylem forms a woody cylinder just inside this layer, masses of xylem and phloëm being paired. Inside the xylem is the pith. Bast fibers are found bordering the phloem. It is the special development of these fibers that makes the flax plant valuable. A layer of cambium is found between the rings of phloëm and xylem in dicotyledonous plants. This layer has the ability of increasing the number of vascular bundles. Grasses and other monocotyledonous stems having no cambium are not able to increase the number of vascular bundles or the diameter of the culms or stems after they are once formed.

81. Buds. Buds produce new stems, leaves, or flowers. The location of buds on the plant normally will tell us what they will produce.

82. Roots. The roots support the plant and absorb water and dissolved substances from the soil. Root hairs are the principal water absorbing parts of the root system. They are found near the growing tip of the root and are projections from the outer layer of cells of this portion of the root. These root hairs are not permanent but die off in a short time, and new ones are constantly being formed near the growing tip of the root. Water can scarcely get into the older woody roots due to the fact that they are covered with hard-walled cells or corky tissue. (See Chapter V.)

Growth Processes

83. Growth Summary. The growth of a plant is the development by multiplication and enlargement of its individual cells. Cell growth has several phases. The first is cell formation by division. The second phase is one of enlargement during which the cell attains its mature size. The third phase is maturation, during which the cell walls are thickened and other changes take place. In the growing region of the plant the fully developed cell again divides. For growth to take place the cell wall must be somewhat stretched and additional cellulose added. This stretching of the cell wall is caused by turgidity.

The rate of plant growth depends internally on many factors, among which are the rate at which food materials are supplied, and on the supply of energy obtained from the oxidation of sugars. A proper temperature is essential, and while light is not necessary for growth, it is necessary for photosynthesis which results in the combination of some plant nutrients into plant foods. The plant nutrients are the raw materials, such as carbon dioxide, water, nitrogen, and phosphorus.

84. Photosynthesis. Green plants have the special ability of making carbohydrates from carbon dioxide and water with the aid of light. The chlorophyls, which are the green pigments in the leaves, are the only known substances with power to combine these materials into carbohydrates. Energy is stored in these manufactured products and the release of this energy is our greatest source of power and the ultimate source of all foods for plants, animals, and man. Coal, the resulting product from plant growth of centuries ago, now makes most of our commercial manufacturing dependent on photosynthetic energy. Agricultural operations involving the production and utilization of animals are directly dependent upon foods manufactured by green plants. More than 90 per cent of the dry weight of most plants consists of carbohydrates derived by photosynthesis from carbon dioxide and water.

The process of photosynthesis is the combining of carbon dioxide and water by the chlorophyl of the plants in the presence of light. As an end result of this process oxygen is liberated and carbohydrates are formed. The exact chemical process taking place during photosynthesis is not known. The carbon dioxide enters the plant through the stomata and diffuses through the water to the chloroplasts. With the aid of the chlorophyl and light, carbon dioxide and water are transformed into carbohydrates. It is supposed that the first product is one of the simpler sugars, probably grape sugar, $C_6H_{12}O_6$, from which more complicated carbohydrates may be obtained by chemical changes.

In the photosynthetic process radiant energy from the sun is stored in the same amount as would be released by oxidizing or burning the material produced. The energy that coal gives off on burning is the energy absorbed and stored during the growth of the plants, of which the coal is the temporary product.

Proteins may be manufactured in the leaves, but light is not necessary for this process. The carbohydrates formed are combined with nitrogen and other substances to make amino acids and these are, probably after being moved some distance, combined into the proteins.

The photosynthetic process is influenced by many growth factors. Among the internal factors are the temperature of the leaves, the quantity of chlorophyl, the supply of water, and the rate of movement of materials away from the place of manufacture. The external factors are the temperature of the atmosphere; the quality, intensity, and duration of light; and the rate of supply of carbon dioxide.[2]

Briggs found that plants of the grass type with food stored outside the cotyledon do not start photosynthetic activity until they have been exposed to light for some time.[3] Seedling plants of the legumes may start photosynthesis immediately with the formation of chlorophyl.

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[2] Stiles, W.—*Photosynthesis*, p. 174. Longmans, Green & Co. London. 1925.

[3] Briggs, G. E.—"The Development of Photosynthetic Activity during Germination." *Roy. Soc.* [*London*] *Proc., Ser. B.*, Vol. 94, pp. 12-19. 1922.

Seedlings which have no chlorophyl, **albinos**, die as soon as they have used all the food supply stored in the seed.

85. Chlorophyl. The amount of chlorophyl in the plant varies from none to about two per cent of the dry matter in a dark green plant. The green color is usually a fair indication of the conditions of growth and the supply of necessary substances. As a rule, the more chlorophyl a plant has the greater will be its rate of carbon assimilation or photosynthesis. The optimum for most species is a normal green but for certain species the yellow-green varieties seem to manufacture food at a faster rate than the darker ones. The red color of certain normal leaves, due to anthocyanin, does not hinder photosynthetic activity if the normal chlorophyl is present also. The red color only hides the chlorophyl.

86. Respiration. Respiration in plants, basically, is very much like that in animals and is a process distinct from photosynthesis. Substances are oxidized, or used in the presence of oxygen, finally producing carbon dioxide and water and releasing energy. This process takes place within the cell and in this way the plant gets its energy for various kinds of work. This series of processes that set energy free in the living organism are grouped together as the process of respiration. Whenever growth is taking place or life is present, respiration goes on. During the dormant periods of plants, this process continues and even seed while in a resting stage are respiring slowly.

There are two kinds of respiration,—anaërobic and aërobic. Anaërobic respiration, or fermentation, takes place in the absence of free oxygen. The oxygen used in anaërobic respiration usually is derived from compounds which also contain carbon and hydrogen, the oxygen being liberated by the breaking down of these compounds through the action of fermentation enzymes. The products resulting are incompletely oxidized and acids and alcohols arise.

Aërobic respiration is an essential respiration in most living protoplasm. It takes place in the presence of free oxygen and usually results in complete oxidation with the formation of carbon dioxide and water. The principal substance oxidized in plant respiration is the carbohydrate material, although other products may be used under certain conditions. Proteins are not generally used although they may be broken down and the carbohydrate portion used in respiration. Respiration processes, both anaërobic and aërobic, are controlled by enzymes formed in the protoplasm.

Heating of grain in the stack or bin, of hay in the stack, mow, or bale, and of silage in the silo is due to respiration, both anaërobic and aërobic, but mostly the former. (See hay curing.)

It has been found that the general effect of the reduction or absence of oxygen upon respiration is to decrease its intensity.[4] All investigators are in accord in finding excessive amounts of carbon dioxide very injurious. Clements states: "The amount required to cause injury in mesophytes (common vegetation) ranges from 5 to 10 per cent, but in hydrophytes (water plants) and some xerophytes (desert plants growing with but little water) especially, it may be as high as 20 per cent, and, in exceptional cases, even higher."

Plants generally demand oxygen in respiration just as animals do, and they will die of suffocation if it is not available. The plant must have oxygen available for all of its parts. Roots ordinarily secure their oxygen from the soil rather than through the leaves.

Respiration goes on both day and night. During the day photosynthesis normally proceeds at a faster rate than respiration so the carbon dioxide liberated in respiration is more than balanced by the oxygen liberated by photosynthesis. At night the plant gives off carbon dioxide, as the respiration continues during the night while photosynthesis ceases in the dark. Respiration uses oxygen and liberates carbon dioxide while photosynthesis uses carbon dioxide and liberates oxygen. Respiration occurs in all living protoplasm. Photosynthesis occurs only in the plastids containing chlorophyl (chloroplasts).

87. Transpiration. Water enters the plant by diffusion through the walls of the root hairs and other tender cells, passes deeper into the root to the fibrovascular bundles, into the xylem, and up through the stems to the leaves. Part of the water is used in photosynthesis and part in other cell processes, but the great bulk of it passes into the air spaces between the cells and diffuses into the atmosphere through the stomata. This water loss is called transpiration; and, while it has some beneficial effects, it often results in the death of the plant. Transpiration is the inevitable result of the necessity of leaving the leaf partially open so that carbon dioxide may diffuse in from the air and be absorbed. The epidermis with its stomata is wonderfully effective in reducing water loss by transpiration without greatly hindering the absorption of carbon dioxide, but the two processes cannot be separated under conditions favorable for plant growth. The stoma should be considered as a mechanism permitting the entrance of carbon dioxide and at the same time preventing in so far as practical the loss of water from the plant. The stoma normally closes at night when photosynthesis and the demand for carbon dioxide has stopped. (See Chap. VI.)

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[4] Clements, F. E.—"Aeration and Air Content." *Carnegie Inst. Wash. Pub. No. 315*, p. 87. 1921.

88. Diffusion and Osmosis. The ultimate particles of gases, liquids, and of substances in solution are in motion and are always tending to spread out away from each other, distributing themselves as uniformly as possible throughout all the available space. This tendency is called diffusion. It is not a current flow but a mixing together. If two miscible substances are put into a closed container, each occupying one-half and with a partition between them, and the partition then removed without creating a current, the substances will each diffuse or spread out into the half originally occupied by the other, until each is equally concentrated throughout the container. If a membrane which will permit the passage of both substances is placed across the compartments, the final result will be the same as if no membrane were there. If the membrane permits one substance to penetrate and not the other, one will be found to be distributed throughout the entire container while the other is confined to its original area.

Any substance in solution (solute) tends to go from a region of high concentration of that solute to a region where there is less of it. Likewise, any solvent tends to go from the region where there is more to the region where there is less of the solvent. If pure water is brought into contact with a strong solution of sugar in water, the sugar tends to spread out into the pure water and the pure water diffuses into the sugar-water solution. In each case the substance is moving from the place of high to the region of lower concentration.

If the sugar solution is enclosed in a membrane impermeable to sugar but permeable to water, the tendency is the same as above described. The sugar cannot pass the membrane, as it is mechanically held back, but the water will pass into the sugar-water solution and will increase the pressure inside. As this pressure increases, it is more difficult for the water to enter, and the amount of internal pressure necessary to prevent the entrance of the pure water is called the osmotic pressure and is usually expressed in atmospheres. The process of osmosis is merely diffusion through a membrane.

In the cells of the roots in contact with the soil solution the cell walls divide two solutions each containing many solutes. Normally there is less water inside the cell than in the soil solution and water tends to pass in through the semi-permeable cell wall.

89. Movement of Materials into the Plant. The solutes in the soil solution may be divided roughly into three classes: (a) Solutes used by the plant; (b) Solutes capable of entering the cell wall but not used by the plant, and (c) Solutes prevented from entering by the cell wall or by other means.

a. Solutes used by the plant. These solutes pass through the cell wall by osmosis until they are equally distributed in the cell sap and in the soil solution; but, as they are being used by the plant and taken out of solution within the cell, there tends to be a continuous flow into the plant. These solutes, in an ionized state, passing through the cell wall may be immediately combined, precipitated, or changed, so that at once they are rendered inactive in so far as their preventing the entrance of other ions of the same kind is concerned. This is probably very common and has been noted particularly with reference to the absorption of practically all of the nitrates in solution from field soils.

Parker[5] studied the absorption of phosphorus from culture solutions and found one corn plant using the PO_4 content of 7500 cc. of water at such a rate that when the PO_4 content was replaced twice daily the solution was not maintained at a concentration of 0.10 parts per million.

The flow of a particular solute into the plan is not uniform, as the needs of the plant vary. At particular seasons of the year the solute may be used rapidly and at other times scarcely at all.

b. Solutes capable of passing through the cell wall but not used by the plant. These solutes pass into the cell and as they are not used by the plant there is soon as much of the solute per unit volume inside the plant as in the soil solution. When this point of equilibrium is reached, this solute does not change in concentration on either side of the membrane until there is a change in concentration either in the plant by an increase in volume or in the soil solution. Water may be freely moving from the soil solution into the plant but it would not carry these solutes in with it after the equilibrium of the solute is established. Certain of this type of solutes may be precipitated in the plant and permit the entrance of a larger amount.

c. Solutes prevented from entering by the cell wall. These solutes are mechanically kept out of the plant due to the impermeability of the cell wall to them. Many salts in combined forms are of this type, and they must be changed to some other form before they can be used. Many of the elements necessary for plant growth are combined in such a way as to render them unavailable. As long as the physical, chemical, and biological conditions are right, the necessary elements are rendered available; but under abnormal conditions corrective measures must be taken to bring about the desired release of the essential substances.

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[5] Parker, F. W.—"Phosphorus Nutrition of Plants." *Ala. Agr. Exp. Sta. Ann. Rpt.* 37, p. 9. 1927.

Water may enter the plant, leaving behind any of these three types of substances in solution if there already is an equal concentration of these substances inside and outside the plant. Likewise, ions of potassium or of other required substances may move into the plant through the water although the water itself is not moving in at the time. Any substance to which the cell wall is permeable may be found in the plant, then, in the same concentration as in the soil solution, but only those substances which are used or precipitated by the plant so that the concentration within the plant continues to be lower than that without will be accumulated.

90. Turgidity. Cells of common crop plants do not grow unless they are turgid. A cell which is so filled that the wall is stretched or under strain is said to be turgid or to show turgor pressure. Turgor is really an expression of osmotic pressure in the cell by the strain on the cell wall. Under certain conditions this pressure, due to a free supply of water outside, may become so great as to rupture the cell wall.

If tissues are surrounded by solutions containing a greater concentration of solutes than is contained within the tissue, water will diffuse out of the tissue, resulting in the protoplasmic membrane pulling away from the cell wall and the cell becoming placid or wilted. This loss of water is called plasmolysis.

Turgor pressure, especially in the roots, has been used as an aid in explaining the movement of water up through the plant. Several references are available attempting a clear explanation of this pressure and its results.[6, 7]

91. Tensile Strength or Cohesion Theory. Dixon[8] has presented a theory of water movement in the plant in which the force effecting the movement is the inhibition of water by the cell walls. The attraction for water is increased as transpiration tends to dry the outer cells. The outer cells may be said, in turn, to call on those next to them so that by the time the vascular bundle is reached, an appreciable force is developed.

The whole mass of water of the vascular system is under stress or pull due to the demand of the large exposed cell area. The whole above-ground column of water is pulled upward as the water freely enters from the soil and there is no appreciable evaporation from the root system to hold it back.

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[6] Livingston, Burton Edward.—*The Rôle of Diffusion and Osmotic Pressure in Plants.* University of Chicago Press. Chicago, Ill. 1903.

[7] Washburn, E. W.—*An Introduction to the Principles of Physical Chemistry.* Second Edition. McGraw-Hill Book Co. New York. 1921.

[8] Dixon, H. H.—*Transpiration and the Ascent of Sap in Plants.* Macmillan and Co. London. 1914.

Copeland[9] constructed an apparatus through which water rose 40 feet, but he did not think the cohesion theory accounted for the rise. After a rather extensive review of the theories regarding the transpiration stream, he states that the rise of water to make good the loss by transpiration is due to the pressure of the atmosphere, or to this and other forces coöperating with and regulated by it.

92. Growth Processes in Plants and Animals Compared. Plants, like animals, should be considered as unified organisms, each part of the plant with definite functions to perform, for fundamentally the growth processes of plants and animals are much the same. Protoplasm is the living material in both plants and animals, and its requirements for growth are much the same wherever it occurs. Protoplasm uses oxygen in oxidizing substances, thereby gaining energy for further processes in plants as well as in animals. In each, the food materials used in growth are carbohydrates, fats, and proteins.

Some plants actually catch and digest insects much as animals digest food. The digestive tract of the animal is comparable to the absorption by the root hairs of the plant. Digestive enzymes are secreted by the protoplasm of animal cells similar to those secreted by plants and for similar or identical purposes. The gaseous exchange through the stomata of plants is comparable with that in the lungs of animals. One of the products of respiration in plants is asparagin, a substance analogous to urea in animals.

The process of photosynthesis is the means by which a plant gets its raw materials into a usable form and is not duplicated in the animal body, although the chlorophyl of plants and hæmoglobin of animals are closely related chemically.

In general, plants differ from animals in that they have definite points at which growth occurs while animals do not have these growing points.

93. Changes from Vegetative Type of Growth to Flowering and Maturity. What causes plants to turn from a vegetative development and start flowering and fruiting? Why do plants shed their leaves and take on a dormant condition in the fall? Are these changes brought about by changes in temperature as has been generally supposed?

a. Coville[10] took up a healthy growing blueberry plant at the end of the summer and carried it to the greenhouse intending to use it for breeding purposes during the winter. The plant refused to continue growth during the autumn although temperature, soil, and moisture conditions were right; it shed its leaves and entered into a condition of complete dormancy as did the plants which were left outside.

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[9] Copeland, E. B.—"The Rise of the Transpiration Stream. An Historical and Critical Discussion." *Bot. Gaz.* Vol. 34, No. 3, p. 161 and No. 4, p. 260. 1902.

[10] Coville, Frederick V.—"The Influence of Cold in Stimulating the Growth of Plants." *Jour. Agr. Res.* Vol. 20, No. 2, pp. 151-160. Oct. 15, 1920.

Blueberry plants kept in the greenhouse all winter remained in a dormant stage the following spring when other plants took on a new growth. Plants which he chilled for several months made the normal spring development. When only a part of the plant was chilled, the portion chilled took on new growth but branches not chilled remained dormant.

Coville explains the work of chilling as resulting in a weakening of the cells permitting enzymes, held within the cells, to get in contact with the starch stored in the plant. This starch is changed to sugar by the enzymes, and sugar, being a soluble plant food, starts the growth, while the comparatively inert starch has little effect either as a plant food or as a means of increasing turgor pressure.

b. Another interesting observation, bearing on factors affecting the change from one type of development to another, has been made by Murneek[11] on the vegetative growth of the tomato plant. On small, nitrogen-starved plants, one small fruit was sufficient to inhibit vegetative growth, while 30 large fruits were necessary to check vegetative growth on strongly vegetative plants. The removal of the fruit in both cases resulted in a complete recovery of vegetativeness.

c. Hartwell[12] found that many factors, correlated in each case with retarded growth of plants, were associated with an accumulation of starch in the above-ground portion of the plant. His work was chiefly with potatoes.

d. Several investigators have pointed out the general relation between the type of growth a plant will make in response to certain changes in the food supply and environment, or the response of the plant to variations in the essential requirements for growth. An abundance of moisture and mineral nutrients and an available carbohydrate supply result in vegetative development at the expense of flowering and fruiting; while, if the plant has an available carbohydrate supply, a reduction in necessary nutrients, particularly nitrogen, induces a decrease in vegetativeness and an increase in fruiting. With a still greater reduction both fruiting and vegetation are suppressed.

Some applications of this nutrient,[13] food balance have been suggested by Kraus and Kraybill and Garner and Allard.[14] Fertilizers containing nitrogen will stimulate vegetative response and will increase or decrease fruitfulness depending on the supply of carbohydrates. If moisture and nitrates are present in sufficient quantities so that the plant is making a strong vegetative growth, decreasing the cultivation will stimulate fruitfulness. Pruning fruit trees affects the carbohydrate-nitrogen relation in the plant and either retards or stimulates fruitfulness as it affects this balance. Girdling also modifies the carbohydrate-nitrogen relationship.

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[11] Murneek, A. E.—"Effects of Fruit on Vegetative Growth in Plants." *Amer. Soc. Hort. Sci. Proc. 21*, pp. 274-276. 1924.

[12] Hartwell, Burt L.—"Starch Congestion Accompanying Certain Factors Which Retard Plant Growth." *R. I. Agr. Expt. Sta. Bul. 165*, p. 23. 1916.

[13] Kraus, E. J. and Kraybill, H. R.—"Vegetation and Reproduction with Special Reference to the Tomato." *Ore. Agr. Expt. Sta. Bul. 149*, p. 6. 1918.

e. After pointing out the close association of carbohydrate accumulation with the rest period and fruit bud differentiation in some fruits, Hooker[15] deems it likely that this accumulation in the vicinity of the buds may affect morphological development of the growing point in such a way as to suppress the development of photosynthetic machinery and thus favor flowering.

f. Garner and Allard's length-of-day theory or photoperiodism in plants is a suggested explanation of seasonal response in type of growth of plants which has had wide consideration. Their work, which pioneered this field, first appeared in 1920. This work bears largely on the carbohydrate supply. (Par. 54.)

g. Other investigators have studied light relations of plants. Wanser[16] claims that day length, independent of temperature, will control the type of growth in winter wheat, and that by regulating this environmental factor, jointing and heading may be controlled independently of the season.

h. Eaton[17] has recently found that the time of flowering of Peking soybeans can be influenced to an extent comparable with the differences due to varying the day lengths if the plants are subjected to high, low, and uncontrolled nightly temperatures.

i. Adams[18] concludes that the reproductive activity, as well as the other activities of the plant, depends largely on photosynthesis, and the amount of photosynthesis is largely dependent upon the intensity of the light, its duration, and the temperature. He also states that it is probable that a higher temperature with light of a given intensity for a definite duration will produce the same photosynthetic result as a lower temperature with light of the same intensity acting for a longer period.

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[14] Garner, W. W., and Allard, H. A.—"Effect of the Relative Length of Day and Night and Other Factors of the Environment on Growth and Reproduction in Plants." *Jour. Agr. Res.* Vol. 18, No. 11, pp. 553-606. Mar. 1, 1920.

[15] Hooker, H. D.—"Fruit Bud Formation and Growth." *Amer. Soc. Hort. Sci. Proc. 22*, pp. 123-126. 1925.

[16] Wanser, H. M.—"Photoperiodism of Wheat; a Determining Factor in Acclimatization." *Science N. S.* 56, pp. 313-315. Sept. 15, 1922.

[17] Eaton, Frank M.—"Assimilation-Respiration Balance as Related to Length of Day Reactions of Soybeans." *Bot. Gaz.* 77, No. 3, pp. 311-321. May, 1924.

[18] Adams, J.—"Duration of Light and Growth." *Ann. Bot.* [*London*] 38, No. 151, pp. 509-523. July, 1924.

j. Temperature was found by Gilbert[19] to be a determining factor in influencing the time of flowering. This temperature effect, however, was closely associated with a response to relative day length.

94. Response of the Plant to Environment. The character of the growth made by a plant may be modified greatly by outside environmental conditions. An extreme response to changes in this respect is seen in the case of the Jerusalem Artichoke. This plant grows normally like a sunflower, tall and somewhat branching. When taken to high altitudes it makes very little stem growth and produces a rosette of leaves close to the ground. Many other plants behave in a somewhat similar manner. Altitude generally has this effect of shortening the stems of plants.

95. Lodging. Growing plants in dense masses with a lack of light often induces an abnormally large stem growth. In darkness potato sprouts grow to extreme lengths. This over-elongation in a thick rank growth of small grains and other crops is accompanied by weakened cells, causing a tendency toward lodging, falling or bending over. (See Small Grain.) Varieties differ greatly in their resistance to lodging.

96. Tillering and Suckering. Tillering and suckering are adjustments of the plant to conditions of growth. This branching of the plant at or near the crown, so that additional plants come from one seed, is a response to general growth conditions. Varieties differ in their tendency to branch, but it may be stated as a general rule that the more favorable the growth conditions the greater the amount of branching. Plants in this way have a tendency to use up the available nutrients. (See Corn Suckering, also Small Grain Tillering.)

Other responses of the plants are made by the roots. Soil, water, and root relations to growth are discussed fully in other chapters.

Necessary Plant Nutrients and Their Rôle in Plant Growth

97. Necessary Plant Nutrients. The plant must have the following elements in an available form for normal growth: nitrogen, phosphorus, potassium, calcium, sulphur, magnesium, iron, boron, manganese, silicon, and zinc. Some physiologists are inclined to include also aluminium, chlorine, sodium, copper, and rubidium, although these last five have not been definitely accepted as essential. In addition, the plant must have carbon, hydrogen, and oxygen. The carbon comes from carbon dioxide. The hydrogen is obtained almost exclusively from water, while the oxygen is obtained from water, from carbon dioxide, from the air, and from certain compounds containing oxygen. Some of these nutrients enter the plant as gases but all finally enter the ordinary cell dissolved in water.

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[19] Gilbert, B. E.—"Interrelation of Relative Day Length and Temperature." *Bot. Gaz.* 81, p. 22. 1926.

Other substances are found in the ash of plants and may be necessary for certain plants. Silicon, found abundantly in the ash of plants, was formerly supposed to prevent lodging as it was deposited in the cell walls; but it has been shown that plants grown in artificial media apparently develop normally with only small quantities of silicon. Stony deposits of silicon in the straw and glumes of grains may serve as a protection against various insects and molds.

Zinc has been shown to have some effect on the metabolism of molds. Aluminium does not ordinarily occur in plant ash. When soil conditions are such that aluminium accumulates in the plant, it quickly becomes toxic. Very small quantities of aluminum may, however, be necessary for growth.

Substances which do not have a direct function in cell structure may act as catalyzers; for example, iron seems to be the basis for a certain enzyme.

98. Nitrogen. Of all the essential plant nutrients nitrogen is perhaps most easily lost from the soil and is one of the most expensive to replace. Nitrogen occurs in the soil in the form of organic compounds, ammonium salts, nitrates, and, to a limited extent, nitrites. Nitrification, which is due to bacterial activity, serves to change certain forms of nitrogen into nitrates.

Atmospheric nitrogen is fixed by certain bacteria in nodules which form on the roots of leguminous plants. The plant protects the bacteria from the air giving them the anaërobic conditions they need and probably supplying them with sugars. The plants assimilate a portion of the nitrogen fixed by the bacteria. The relation is mutually beneficial or symbiotic. Another group of bacteria which live on decaying organic matter, as, for example, the azotobacter, may gather free nitrogen from the soil air.

Ammonium salts and nitrites are absorbed and held by the soil but nitrates are not so strongly held. The plant uses nitrogen in the form of nitrates and it is in this form that most of the nitrogen is lost by leaching. The nitrates are combined with some of the simpler carbohydrates and often with sulphur to form the simpler proteins. Some plants, as, for example, rice, and probably many marsh plants, can use nitrogen in the form of ammonia.

An abundant supply of nitrogen favors vegetative development in the plant, delays maturity, and gives a dark green appearance.

If nitrogen in an available form is deficient in the soil, the vegetative development of the plant is checked so that stunted plants result. Nitrogen deficiency may be indicated by a yellowing of the leaves such as occurs on poorly drained soils.

99. Phosphorus. The phosphorus used by the plant is obtained as the PO_4 ion from phosphoric acid, H_3PO_4. Phosphorus is a necessary constituent of a special group of proteins called nucleins and of substances called phosphatides contained in the protoplasm. The simpler proteins combine with the nucleins to form the nuclear proteins of which phosphorus is an essential constituent. Thus the phosphorus is directly connected with cell multiplication and with seed formation. Phosphorus hastens the maturity of the plant and stimulates the translocation of materials within the plant. It stimulates the production of grain in proportion to that of straw. Investigations have shown that it brings about a stimulation of root development in the early stages of plant growth.

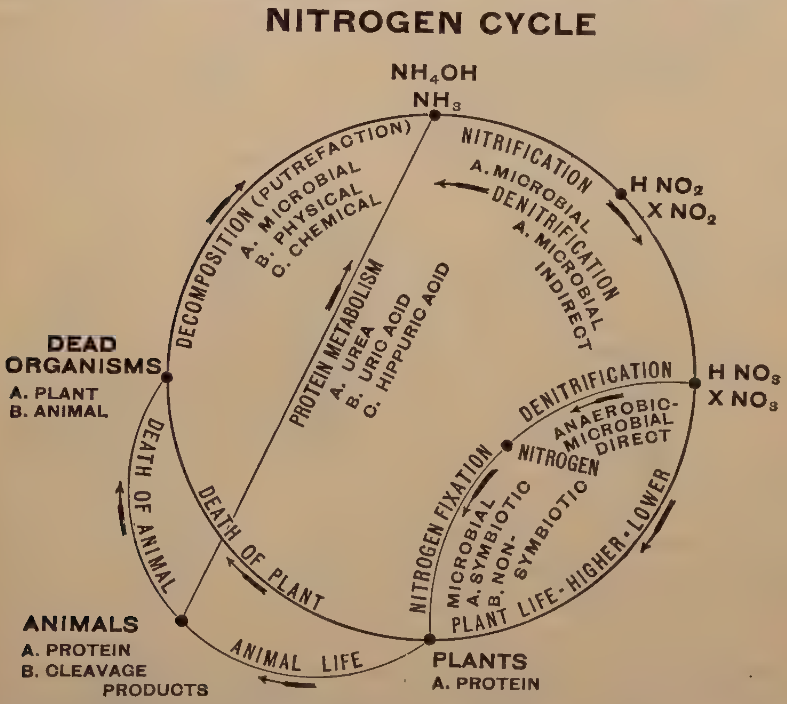
NITROGEN CYCLE
NH₄OH
NH₃
H NO₂
X NO₂
H NO₃
X NO₃
DEAD ORGANISMS
A. PLANT
B. ANIMAL
ANIMALS
A. PROTEIN
B. CLEAVAGE PRODUCTS
PLANTS
A. PROTEIN
NITROGEN
DECOMPOSITION (PUTREFACTION)
A. MICROBIAL
B. PHYSICAL
C. CHEMICAL
NITRIFICATION
A. MICROBIAL
DENITRIFICATION
A. MICROBIAL
INDIRECT
PROTEIN METABOLISM
A. UREA
B. URIC ACID
C. HIPPURIC ACID
DENITRIFICATION
ANAEROBIC-
MICROBIAL
DIRECT
NITROGEN FIXATION
MICROBIAL
A. SYMBIOTIC
B. NON-SYMBIOTIC
PLANT LIFE-HIGHER-LOWER
DEATH OF ANIMAL
DEATH OF PLANT
ANIMAL LIFE

FIG. 39.—A graphic illustration of the nitrogen cycle. (After Giltner and Snyder, Mich. Quart. Bul., Vol. 6, 1924.)

Lack of phosphorus may be indicated by too small a proportion of grain to straw and by delayed maturity. Noll[20] has observed that though phosphates show a more marked influence in promoting earliness than the other fertilizer elements, yet moderate applications of nitrogen and potash, where these elements are somewhat deficient for the production of crops, have a similar effect. Lime also, if applied to soils having a high lime requirement, may induce earlier ripening.

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[20] Noll, Charles F.—"Effects of Phosphates on Early Growth and Maturity." *Jour. Amer. Soc. Agron.* Vol. 15, No. 3, p. 98. Mar., 1923.

100. Potassium. The definite place of this element is not clear but it is connected with protoplasm formation and tends to balance the fruiting and vegetative tendencies of the plant giving a better proportion between the two. Insufficient potassium may result in premature ripening or drying of the stems with the grain or seeds immature. Root crops and crops on peaty soils are most likely to respond to potassium fertilizers. Weak stems, though usually resulting from a rapid, rank growth, may be caused by a lack of potassium.

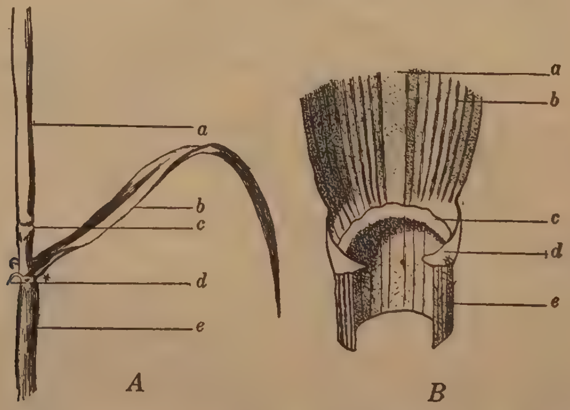

FIG. 40.—Culm and leaf parts in grass. *Aa,* internode; *Ab,* leaf blade; *Ac* node; *Ad,* auricle; *Ae,* leaf sheath; *Ba,* mid rib; *Bb,* leaf blade; *Bc,* ligule; *Bd,* auricle; *Be,* leaf sheath.

101. Calcium. Calcium, the essential element supplied in lime, is necessary for proper leaf and cell wall development. Limestone is the form in which calcium is usually supplied, and it improves the physical tilth of the soil by its flocculating effect. It corrects acidity and provides the proper reaction for certain bacterial activities.

102. Sulphur. Sulphur is essential in the formation of proteins. It is used in the sulphate form of one of the essential metals. Other sulphur compounds are generally injurious.

103. Magnesium. Magnesium is essential in the chlorophyl molecule and also accompanies proteins.

104. Iron. The lack of iron prevents chlorophyl formation, making the leaves pale and chlorotic. It has been suggested that iron is used in the formation of an enzyme for the production of chlorophyl.

BOTANICAL CHARACTERISTICS OF CROP PLANTS

There are two great outstanding groups of plants of more importance from the standpoint of crop production than any others: these are the grasses and the legumes. The species and varieties within each of these groups have certain common characteristics which it is well to recognize.

105. The Grasses. The grasses are characterized by having jointed, hollow, or pithy stems with cross partitions at the nodes. The two-ranked, parallel veined, simple leaves are composed of a leaf blade and sheath with a ligule at the junction of the two parts. The sheath encloses the stem. Inconspicuous flowers are borne in spikelets, with two ranked bracts or scales on the central axis or rachilla. The outer bracts are the empty glumes or outer glumes; next to these are the lemmas, then the kernels or flowers, then the palea. Flowers are usually perfect with three stamens and two plume-like stigmas. At the base of the ovary are two or three scale-like bracts called lodicules, which suggest the petals of less specialized flowers.

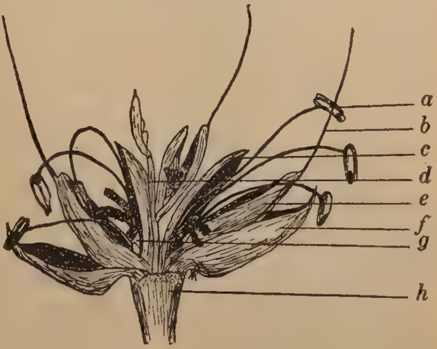

FIG. 41.—The different parts of the wheat spikelet. *a*, stamen; *b*, awn; *c*, palea; *d*, rachilla; *e*, lemma; *f*, outer-glume; *g*, pistil; *h*, rachis.

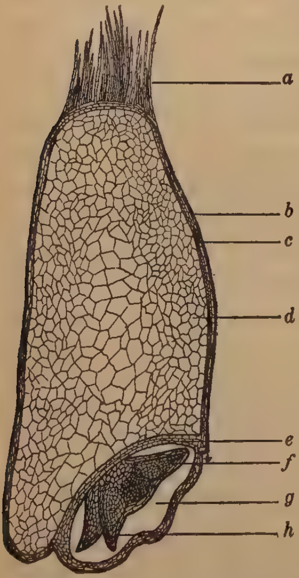

FIG. 42.—Cross section of a grain of wheat. *a*, brush; *b*, bran layer; *c*, aleurone layer; *d*, endosperm; *e*, epithelial cells; *f*, plumule; *g*, air space around the germ; *h*, radicle.

The fruit, kernel, or grain is monocotyledonous, consisting of the embryo with the surrounding scutellum, or cotyledon, and the endosperm. The embryo or germ is located along one side toward the end of the kernel, as in corn or wheat, and consists of the plumule, radicle, and scutellum. The plumule, following germination, develops into the above ground portion of the plant and the crown or permanent roots.

The radicle develops into the primary or seedling root system the function of which is to anchor the seed and absorb water. The scutellum, or remainder of the germ, secretes from its outer layer of cells certain enzymes which dissolve the neighboring endosperm, permitting this dissolved food material to pass into the plumule and radicle. The whole kernel is enclosed in the pericarp which is the developed ovary wall. The parts of the grass seed and plant are illustrated in Figs. 41-43.

106. The Legumes. The legumes have alternate, usually compound leaves with stipules, and the flowers are generally shaped like those of the sweet pea. Seed are dicotyledonous and are borne in a pod which splits. Leguminous plants have the ability to use free atmospheric nitrogen through the activities of certain symbiotic bacteria which multiply and function in nodules developed on the roots of the plants.

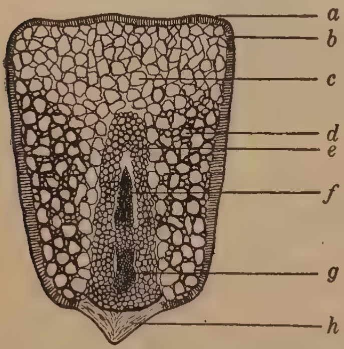

FIG. 43.—Longitudinal section of a corn kernel. *a*, pericarp (hull); *b*, aleurone layer; *c*, endosperm (soft starch); *d*, endosperm (hard starch); *e*, germ; *f*, plumule; *g*, radicle; *h*, tip cap.

In leguminous seed the reserve food is stored in the two cotyledons. Near one end and between the edges of the cotyledons is the plumule, with its embryonic leaves, and the radicle. The whole is enclosed in the testa or seed coat. When germination starts, the radicle pushes out and down developing into the root system. In this case the radicle forms the basis of the permanent root system. The parts of the leguminous seeds and plants are illustrated in Figs. 44 and 47.

CHARACTERISTIC GROWTH OF THE GRASS AND LEGUME GROUPS

107. The Grass Plants. The small grains will be discussed here as characteristic of this group. The seed when planted absorbs water, swells, and germinates, and the plumule and seedling roots break through the seed coat. The plumule pushes to the surface and the leaves open out. At a point just below the surface of the ground, at the first node, the crown roots emerge. These roots are finely divided and spreading, and are known as fibrous roots. The point of separation between the roots and tops is called the crown of the plant. Tillers or branches of the plant come out at the crown or from nodes near the crown of the plant. Buds from which these tillers arise are found at each node inside the leaf sheath. The development so far described

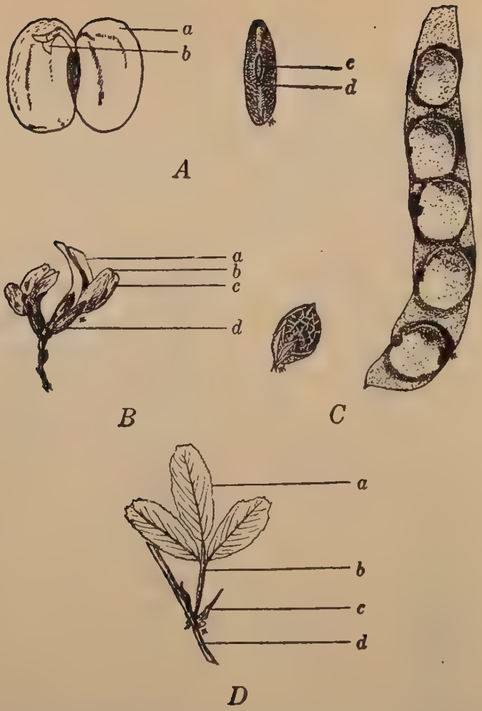

FIG. 44.—Characteristic seed, flower and leaf parts in legumes. *A*, bean seed; *Aa*, cotyledon; *Ab*, seed leaves; *Ac*, hilum; *Ad*, micropyle; *B*, flower; *Ba*, standard; *Bb*, wing; *Bc*, keel; *Bd*, calyx; *C*, sweet clover and bean seed pods; *D*, sweet clover leaf; *Da*, leaflet; *Db*, petiole; *Dc*, stipule; *Dd*, stem or culm.

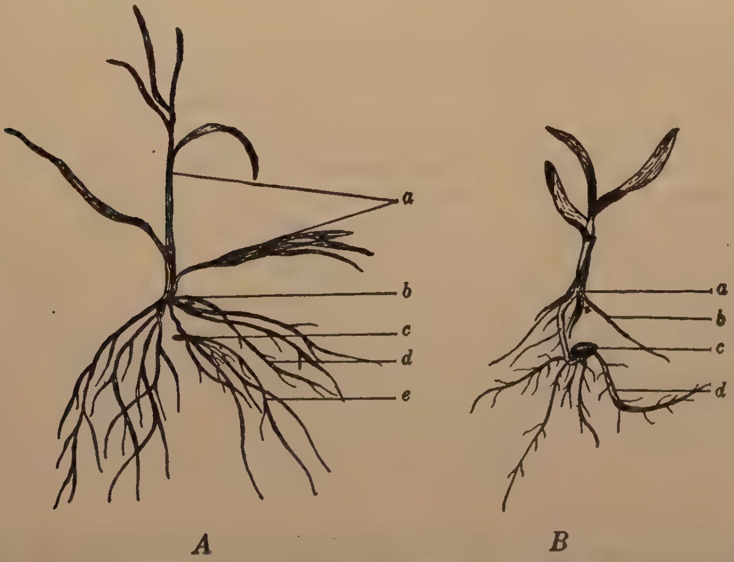

FIG. 45—Characteristic growth of wheat and corn seedlings. *Aa*, leaves; *Ab*, crown; *Ac*, kernel; *Ad*, permanent roots; *Ac*, temporary roots; *Ba*, crown; *Bb*, permanent roots; *Bc*, kernel; *Bd*, temporary roots.

is usually called the seedling stage. The term "jointing stage" is usually applied when the lengthening of the plant is rapid and the nodes begin to appear above the leaf sheaths.

The next stage is the "heading stage" during which the heads emerge. The upper internode elongates so that the head stands at least three or four inches above the top leaf in most small grains. Soon after the heads have emerged, flowers open. In wheat, barley, and oats the flowers open in such a manner that each flower is pollinated by its own pollen (self-pollinated). In rye, cross-pollination is the rule.

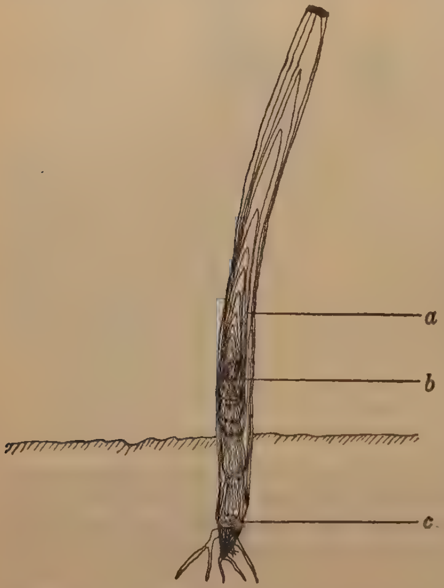

FIG. 46.—Longitudinal section of a grass seedling. *a*, leaf; *b*, growing point; *c*, crown.

If the grain is broken open when it first attains its size, it will be found to be filled with a watery sap, which later turns white as the starch content increases. As the moisture is drawn out or used by the plant, the contents of the kernel becomes a sticky dough and then later firm and hard.

108. The Legumes. The legume seed swells and germinates and the radicle pushes out and downward into the soil. The section of the stem just below the cotyledons (hypocotyl) elongates and either (1) forms an elongated loop which breaks through the ground and then straightens out, pulling the cotyledons and plumule out or (2) remains short and holds the cotyledons below ground while the stem above the cotyledon (epicotyl) elongates, raising the leaves to the surface. Alfalfa, beans, and clover are characteristic of the first type, while peas represent the second type. The root or radicle portion in either case pushes down into the soil, sending out branches. The root system of the legume usually consists of a tap root going relatively deep into the ground with smaller branches or secondary roots branching from it. However, the type of the legume root varies greatly and this is further modified by the character of the soil.

Alfalfa and the biennial and perennial clovers form crowns from which new growth arises in the spring after the winter dormancy. The top portion of the plant may either grow erect and branching or it may be trailing and lie on the ground or climb by clinging to other vegetation.

Flowers of different species have a differing number of ovaries. These vary from one to many, but are fairly constant within the variety.

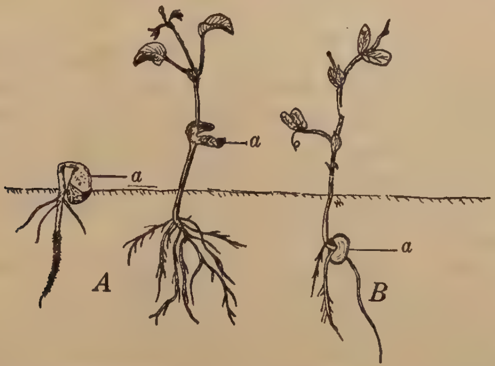

Fig. 47.—*A,* bean seedlings; *B,* pea seedlings. *Aa* and *Ba,* cotyledons.

STUDY QUESTIONS ON CHAPTER IV

1. Why is it possible for a plant to continue to live after a portion of it is dead, when this is not ordinarily possible for animals?
2. Explain photosynthesis, stating the mechanism, materials, and conditions necessary for this process.
3. Why is photosynthesis so important in plant growth?
4. What factors influence the rate of the photosynthetic process?
5. When does respiration take place and why does the plant respire?
6. Considering the activities of the plant both during the day and the night, show how respiration and photosynthesis, together, influence the exchange of gases between the plant and the atmosphere.
7. Explain how substances in the soil solution may enter the plant at different rates; also, how it is possible for one to enter while another, equally soluble, and equally able to pass through the cell wall, does not enter.
8. Explain the prime function of the stomata. What indicates that this is the prime function?
9. Outline the different plant growth processes, their functions and relationships, so that you have a general picture of how plants grow.
10. What is it which causes plants to change from one type of growth to another, at certain times of the year?
11. What causes plants to lodge? How and to what extent can this be prevented?
12. Why do plants tiller or sucker? Is this beneficial or injurious to corn? To small grain?

13. What distinction would you make between plant foods and plant nutrients? List the plant nutrients. What are the plant foods?
14. State the form in which each of the essential plant nutrients are used, the function, and the symptoms of deficiency.

APPLICATION ASSIGNMENTS ON CHAPTER IV

1. Lying in the shade of a tree, you are in a meditative mood. Before you is a plant. It has spent its life thus far in that one spot and will die there; it cannot go and get water nor food; if these are not all supplied the plant dies. A man would soon perish under similar conditions. You decide that the plant responds directly to the natural laws under which it lives. Write your meditations, showing and simplifying the processes involved in its life and growth.
2. You accidentally sprayed the leaves of a plant with shellac from a spray gun. A week later you observe the plant. What do you note? Why?
3. During a week of hot, sultry, rainy weather the air is saturated with water. What plant growth process might one expect to be influenced by this condition? Explain how the plant continues to grow under this situation.
4. You note that a field of corn has become noticeably yellow in color early in the season. What conditions might cause this?
5. Corn makes a large stalk growth, a relatively feeble root growth and produces but little grain. Give a possible explanation for this condition.
6. An analysis of the soil water available to a plant shows enough of a poison in fifteen pounds to kill the plant if injected into it. Yet the plant passes 300 pounds of the water through its system without injury. The poison can pass freely through the cell walls. Explain.

CHAPTER V

ROOT RELATIONS OF FIELD CROPS

Until in very recent years comparatively little study has been given to the roots of plants. They have not received the attention that their functions warrant. The plant is dependent on its root system for water and nutrients as well as for anchorage in the soil. The roots of many plants also perform an important function in storing up food for future use.

In extent, the root system is usually as great or greater than the above ground portion, while in the case of the perennial legumes, the sugar beets, and most vegetable crops, the root growth is usually several times that of the above ground portion. It has been estimated[1] that the length of the roots of the wheat or oat plant, laid end to end, would be 1600 feet. Clark[2] reports that one squash vine produced 15 miles of roots when laid end to end.

TYPES OF ROOTS

109. Types of Roots. Roots do not possess the symmetry usually noted in the top growth of plants. This is due to the necessity of avoiding obstructions and of securing water, air, and food materials wherever they may be found most abundantly. Within a species the tendency is to produce a certain type of root system; and roots are roughly classed into types which in turn permit of rather wide variation.

Fibrous roots. Corn, wheat, oats, and other grasses have fibrous root systems. In this type there is no one main root. All of the roots are thread-like and finely branched. Certain other crops, e.g., onions, strawberries, and many weeds also have fibrous roots.

Tap roots. The tap root system is one in which there is one large main root from which lateral branches arise. Alfalfa, flax, the clovers, sunflower, and sugar beet are examples of plants having tap roots. The tap root is usually considered a deeper root system than the fibrous one and is commonly found in drouth-resistant plants. Tap roots commonly serve as organs for food storage, as in the case of alfalfa and biennial sweet clover.

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[1] Martin, John N.—*Botany with Agricultural Applications*, p. 1. John Wiley and Sons. New York. 1920.

[2] Clark, William S.—"Observations upon the Phenomena of Plant Life." *Mass. Dept. Agr. Ann. Rpt.* 22, p. 211. 1874.

Fascicled roots. Plants having a cluster of enlarged roots, due to food storage, are said to have fascicled root systems. The sweet potato plant is an example.

Brace roots. The roots arising from the lower nodes above the ground in corn and many other grasses are called prop or brace roots. These roots extend downward and after entering the surface of the soil cannot be distinguished from the other roots in structure or function.

Adventitious roots. Roots occasionally are found arising from leaves or from the stem above ground. They are also found arising from a stem below ground, e.g., in listed corn, transplanted tomato, etc. Roots not arising from the seed or as branches of seed roots, but from stems or leaves, are called adventitious.

Seminal roots. In the grasses the first roots sent out from the radicle of the germinating seed are called seminal or temporary roots. They may function throughout the life of the plant or they may die soon after the permanent roots are established.

Coronal roots. In the grasses the system of roots arising from the crown of the plant and functioning throughout its life make up the coronal or permanent root system.

STRUCTURE OF THE ROOT

110. Form and Structure of Crop Roots. Weaver[3] describes the root structure as follows:

"Roots have a form and structure remarkably adapted to perform their functions of anchorage; and of absorption, conduction and storage of water, nutrients and elaborated foods. As regards origin, the primary root, developing from the lower end of the stem of the embryo, with its branches, may constitute the entire root system, as in beets and many other dicotyledons. But in monocotyledons, like the cereals, as well as in certain other plants, this primary root system is supplemented by a secondary one which consists of branches arising adventitiously from the basal nodes of the stem. An examination of root structure shows that each part or tissue has its special activities to perform. The growing tip of meristem in the zone of division continually produces new cells. These enlarge, chiefly in one direction, just back of the tip in the zone of elongation, and push the growing tip, protected and lubricated by the root cap, into the soil with great force. Its pathway is, in the main, determined by gravity but is also affected by water, air, and other stimuli. The maturing root shows three well-defined regions: epidermis, cortex, and stele or central cylinder. The permeable epidermis, with surface greatly increased by root hairs, absorbs water and nutrients. The abundance of root hairs varies greatly with water content and air supply; there are few or none in very wet soil. The cortex is chiefly active in lateral transport of water and nutrients and in food storage. The tracheary tubes of the stele conduct absorbed materials upward to the green stems and leaves where they, with carbon dioxide from the air, are made into plant foods. These foods, in a soluble form, are transported downward along the phloem highways (sieve tubes, parenchyma) and nourish the growing root. Groups of bast fibers . . . furnish flexibility and tensile strength. The pericycle gives rise to buds which develop into lateral roots having a structure identical with that of the parent, and in these the process of branching is again repeated . . . *The* roots are so numerous that their combined area often exceeds that of the tops.”

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[3] Weaver, John E.—*Root Development of Field Crops*, pp. 51-52. McGraw-Hill Book Co. New York. 1926.

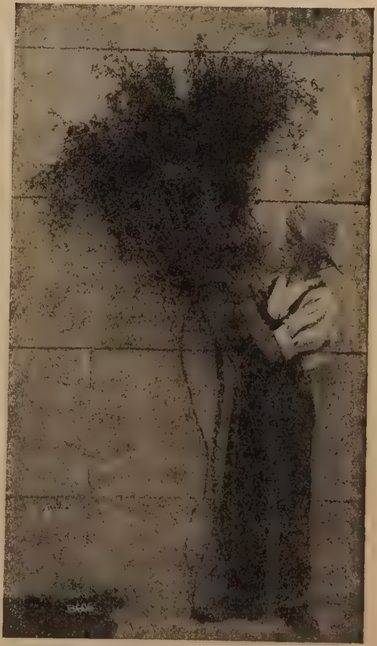

FIG. 48.—An old alfalfa plant at the Iowa Station, showing the character of the root growth which may develop under favorable conditions.

Secretions from the Roots of Growing Plants

111. Root Secretions. When the roots of plants are allowed to make their growth on the surface of a polished marble slab, they etch the surface making a slight depression where-ever the root comes in contact with the marble. This power of roots to render minerals soluble led many to credit roots with the exudation of acids or other substances which dissolved the soil nutrients from the rock particles. These secretions were supposed to accumulate in the soil when a given crop was grown on the land several years in succession making the soil toxic to this particular plant.

112. Theory of Toxic Secretions. Décandolle[4] advanced the theory that the roots of plants excrete substances which are slightly toxic to that particular species of plant and that one of the chief concerns in crop rotation was to grow such crops in succession as were not injured by the toxic excreta of the crop preceding. Liebig, the great German agricultural chemist, believed strongly in Décandolle's theory.

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[4] Décandolle, A. P.—*Physiologie végétale. Excrétions des racines.* Vol. I, p. 248. Béchet jeune. Paris. 1832.

Whitney[5] and Cameron suggest the desirability of including such crops in rotation as will not prove injurious to those which follow; also that sufficient time should elapse between the growing of the same crop to permit the soil to dispose of the root excretions—"sewage."

113. Solvent Effect of Carbon Dioxide. Hall[6] concluded that it was unnecessary to assume that the secretions of a permanent acid from the roots of plants attack the soil materials and bring them into solution. He pointed out that the growing portions of the plant root are always giving off CO_2 and that carbon dioxide, especially in the concentrated solutions which must be momentarily formed in the cell walls of the root hairs, has an appreciable solvent effect upon the majority of minerals composing the soil and that this alone is capable of giving rise to such solutions as are required for the nutrition of the plant.

Stoklasa and Ernest[7] in a study of the chemical nature of the root secretion conclude that CO_2 is the sole substance secreted in normal respiration.

114. Organic Decomposition *vs.* Toxic Secretions. Livingston[8] states that the roots of plants probably do not exude toxic substances in significant amounts but that such secretions (outward diffusion) do occur when active roots are poorly supplied with oxygen. Stoklasa and Ernest are in accord with this opinion. Livingston further suggests that well aërated soils may produce toxins if they are freely supplied with organic material that gives rise to toxic substances.

That some crops do have a depressing effect upon the yields of succeeding crops is well recognized. Kafir[9] has been shown to have a depressing effect upon the yield of wheat. This is attributed to decomposition products rather than root excretions. The yield of corn grown on land after a crop of sudan grass will often be greatly reduced. This effect has generally been credited to a poor physical condition of the soil—a very uncertain and unsatisfactory explanation. Hughes and Wilkins[10] at the Iowa station found as an average for seven years that the yield of corn following sudan grass which was fall plowed was fully as good as corn following either oats or soybeans.

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[5] Whitney, Milton—"Soil Fertility." *U. S. Dept. Agr. Farmers Bul. 257*. 1906.

[6] Hall, A. D.—"The Solvent Action of Roots upon the Soil Particles." *Sci. Prog.*, Vol. 1, p. 51. 1906.

[7] Stoklasa, Julius, and Ernest, Adolf—"Beiträge zur Lösung der Frage der chemischen Natur des Wurzelsekretes." *Jahrb. Wiss. Bot.*, Vol. 46, pp. 55-102. 1908.

[8] Livingston, Burton E.—"Some Physiological Aspects of Soil Toxicity." *Jour. Amer. Soc. Agron.*, Vol. 15, No. 8, p. 321. Aug., 1923.

[9] Sewell, M. C.—"Effect of Andropogon Sorghum on Succeeding Crops of Triticum sativin vulgare." *Bot. Gaz.*, Vol. 75. pp. 1-26. 1923.

FACTORS INFLUENCING THE DEVELOPMENT OF ROOTS

The roots of a number of plants show great similarity when grown in uniform soil. Striking variations are caused by the moisture content, the fertility of the soil, its aëration, and structure. Liebig said, "Plants search for food as if they had eyes."

115. Dry and Moist Soil as Affecting Roots. Weaver[11] reports that corn grown for five weeks in a moist, rich, loess soil with an available water content of 9 per cent, had a root area 2.1 times greater than that of the transpiring surface of stems and leaves, while corn grown under similar conditions, but with an available soil water content of 19 per cent, had a root area only 1.2 times greater than that of the top growth.

Jean and Weaver[12] studied the growth of corn roots in soil varying in fertility and receiving different amounts of water. The root systems were examined at the end of six weeks when the crop was 12 to 15 inches in height. Corn grown on land which had received 5 tons of barnyard manure per acre and was fully irrigated, developed almost all of its roots in the surface 1 foot of soil. Nearly all of these roots were inclined to be parallel with the soil surface, and the bulk of them were in the surface 6 inches of soil, only a few having extended obliquely downward into the second foot of soil.

In similar soil which was neither irrigated nor fertilized and in which only 4 or 5 per cent of available water was present most of the roots grew outward and downward 1 to 2 feet. The longest extended 2.5 feet and then turned downward into the second foot of soil. This growth was typical of most of the roots; the roots seemed to seek more moist soil areas. Some of the more nearly vertical roots even extended a little into the third foot of soil.

Corn grown on a similar area which was lightly irrigated made an intermediate root growth. While the number of roots was approximately the same in all three plots, great differences were noticed in both the number and length of branches. In the fully irrigated soil the branches averaged 12 per inch of main root as compared with 27 in the dry land. In the dry soil the branches were twice as long and had twice as many sublaterals as in the irrigated plots where the branches were only 2 inches long with 9 branchlets per inch on the average.

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[10] Hughes, H. D., and Wilkins, F. S.—"Soybeans for Iowa." *Iowa Agr. Expt. Sta. Bul. 228.* 1925.

[11] Weaver, John E.—"Investigations on the Root Habits of Plants." *Amer. Jour. Bot.*, Vol. 12, pp. 502-509. Oct., 1925.

[12] Jean, F. C., and Weaver, John E.—"Root Behavior and Crop Yield under Irrigation." *Carnegie Int. Wash. Pub. 357.* 1924.

By midseason the roots in the irrigated plots had made a lateral spread of 28 inches and had penetrated to a depth of 28 inches, while on the plot which had received no irrigation, the lateral spread was 42 inches and the maximum penetration 46 inches.

Kiesselbach[13] grew corn on soils with 98, 80, 60, 40, and 20 per cent moisture content and obtained 8.5, 6.7, 6.1, and 5.2 pounds of tops to one pound of roots. Similar results have been reported by Harris.[14]

Miller quotes Von Seelhorst's[15] work on soil moisture in relation to the ratio of tops to roots. Crops were grown on soils with varying per cents of their moisture capacity. The results are given in Table 115a.

115a. Number of pounds of tops to one pound of roots for crops grown on a soil with varying amounts of soil moisture.

PER CENT OF SOIL MOISTURE CONTENT	POUNDS OF TOPS TO ONE POUND OF ROOTS		
	Oats	Spring Wheat	Barley
40	3.3	4.5	4.5
55	4.9	6.6	8.0
70	6.7	5.8	10.8
85	6.4	5.0	8.7

116. Effect of Soil Fertility on Root Development. Sachs[16] as early as 1865 demonstrated that the more concentrated the nutrient solution the shorter were the roots.

Frank[17] observed that a plant grown with half its roots in a container to which nitrogen had been added and the other half in a container to which no fertilizer had been applied developed roots which branched vigorously in the fertilized soil but only sparingly in the soil which was not fertilized.

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[13] Kiesselbach, T. A.—"Transpiration Experiments with the Corn Plant." *Ann. Rpt. Nebr. Agr. Sta. 23*, p. 131. 1910.

[14] Harris, Frank S.—"Effect of Soil Moisture, Plant Food, and Age on the Ratio of Tops to Roots in Plants." *Jour. Amer. Soc. Agron.*, Vol. 6, No. 2, pp. 65-75. Mar.-Apr., 1914.

[15] Von Seelhorst, C.—"Beobachtungen über den Zahl und den Tiefgang der Wurzeln verschiedener Pflanzen bei verschiedener Düngung des Bodens." *Jour. Landw.* Vol. 50, pp. 91-104, 1902. Cited by Miller, E. J. *Jour. Amer. Soc. Agron.*, Vol. 8, No. 3, pp. 143-144. 1916.

[16] Sachs, Julius—*Handbuch der Experimental-Physiologie der Pflanzen*, p. 177. Wilhelm Engelmann, Leipzig. 1865.

[17] Frank, B.—"Die Assimilation des freien Stickstoffs durch die Pflanzenwelt." *Bot. Ztg.*, Vol. 51, Abt. 1, p. 153. 1893.

Nobbe[18] grew corn in 6 cylinders with fertilizer applied to definite areas in each; as for example, in the bottom 2 inches of soil, in a core in the center, etc. Afterwards when the root growth was examined, the form of roots in all 6 cylinders was practically the same, but there was a decided tendency for vigorous branching in the fertilized areas of each pot with a scarcity of branching in the unfertilized areas.

Tucker and Von Seelhorst[19] grew oats in soil varying in moisture content to which different fertilizers were applied. The results are presented in Table 116a.

116a. Pounds tops to one pound of roots when grown with different fertilizers and moisture supply.

PER CENT OF MOISTURE	FERTILIZER USED							
	None	KP	KPN	KP_2N	KN	KN_2P	PN	PN_2K
14	5.4	6.2	6.8	6.2	6.7	7.4	7.1	6.4
18.4	8.9	10.1	13.1	11.0	9.1	12.1	15.2	11.5
22.5	9.4	11.8	15.7	14.8	7.8	14.8	14.0	16.1

His work also shows that the weight of the grain and straw increased with the increasing water content of the soil. The greatest weight of roots was produced with the smallest water content, and the lowest root weight was produced by plants grown in soils with the mean water content.

Livingston[20] studied 17-day-old wheat seedlings grown on poor soil to which varying amounts of manure had been added. The growth of roots increased with the increase in amounts of fertilizers added to the soil. While the number of primary roots remained approximately the same, the number of secondary roots was increased considerably.

117. Effect of Cultural Methods on Root Growth. Ten Eyck[21] reports that listed corn grown on a heavy clay loam 6 to 12 inches deep underlaid by a stiff clay subsoil developed its primary root system deeper in the soil than surface planted corn but that the secondary roots tended to grow upward so that the surface soil was as well filled with secondary roots as when the corn was surface planted.

Georgeson and Payne[22] report that a plot of listed corn receiving

[18] Nobbe, Friedrick—"Über die feinere Verastelung der Pflanzenwurzel." *Landw. Vers. Sta.* Vol. 4, pp. 212-224. 1862.

[19] Tucker, M., and Von Seelhorst, C.—"Der Einfluss der Wassergehalt und der Reichtum des Bodens auf die Ausbildung der Wurzeln und der oberiridschen Organe der Haferpflanze. Ausüben." *Jour. Landw.* Vol. 46, pp. 52-63. 1898.

[20] Livingston, Burton Edward—"Note on the Relation between Growth of Roots and of Tops in Wheat." *Bot. Gaz.*, Vol. 41, pp. 139-143. 1906.

[21] Ten Eyck, A. M.—"Roots of Plants." *Kans. Agr. Expt. Sta. Bul. 127*, pp. 199-252. 1904.

[22] Georgeson, C. C., and Payne, J. E.—"Investigations of the Root Development of Some Forage Plants." *Kans. Agr. Expt. Sta. Bul. 75*, p. 221. 1897.

shallow cultivation had its roots 4 inches from the surface in the middles. Surface planted corn given deep cultivation also had its roots 4 inches from the surface in the middles. In surface planted corn given shallow cultivation the roots were 3 inches deep. When cultivated alternately deep and shallow, they were 5 inches, and when given only surface cultivation they were but 1 inch below the surface in the middles, while in one place fibrous roots mingled with the surface crust. Corn roots on subsoiled plots were found to penetrate 6 feet 9 inches in one case and 5 feet 3 inches in another, while on an ordinary plowed plot the roots were traced to a depth of 6 feet 9 inches.

Weaver[23] reports that when plants are spaced too close together, under otherwise favorable conditions for growth, the plants do not reach a maximum development owing to an insufficient supply of nutrients, water, and light, and, that under these conditions, the root system is more extensive in proportion to the top than for plants less closely spaced.

118. Effect of Aëration on Root Development. Arker[24] found that the rate of root growth of common sunflowers and white lupines in nutrient solutions became increased when a stream of air was constantly pulled through the pots in which the tested plants were grown.

Snow[25] found that the absence of oxygen retarded root growth and stopped the production of root hairs. The reduction of the oxygen pressure to zero stopped the development of root hairs in corn even when all carbon dioxide was removed. With wheat, the root hairs quickly died in the absence of oxygen. Other workers have also found root hair development to be dependent on a supply of oxygen in the soil.

The plant roots, like all other living parts, require oxygen for respiration. Warming[26] states that plants adapted to ordinary soils are suffocated on very wet soils.

Hole and Singh,[27] in a study of the relation of the air content of the soil to growth of *Shorea robusta* found that when the pore space of a soil is reduced by mechanical pressure, 25 per cent more plants may die during rains than in the normal soil.

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[23] Weaver, J. E.—"Investigations on the Root Habits of Plants." *Amer. Jour. Bot.* Vol. 12, pp. 502-509. Oct., 1925.

[24] Arker, Josef—"Die Beeinflussung des Wachsthums der Wurzeln durch das umgebende Medium." *Bot. Centbl.* Vol. 87, p. 433. 1901. (Cited by Miller, E. C. *Jour. Amer. Soc. Agron.* Vol. 8, No. 3, p. 143. 1916.)

[25] Snow, Laetitia Morris—"The Development of Root Hairs." *Bot. Gaz.*, Vol. 40, pp. 12-48. July, 1905.

[26] Warming, E.—*Oecology of Plants*, p. 43. Clarendon Press, Oxford, Eng. 1909.

[27] Hole, R. S., and Singh, P.—Part I. "Soil Composition, Soil Moisture, Soil Aëration." *Indian Forest Rec.* Vol. 5, No. 4, p. 1, 1914.

Hunter[28] placed badly developed seedlings in a soil through which 15 liters of air were drawn each day. With each treatment the plants made marked improvement and became more robust with stronger stems and larger leaves than those of the control plants with which they were compared.

Balls,[29] working with cotton in Egypt, found that raising the water table even temporarily by irrigation resulted in the death of the deeper roots and usually resulted in a decrease in plant growth and in yield.

119. Effect of Drainage on Root Habits. Elliott[30] found that in well drained soils corn roots frequently extended to a depth of 6 feet or more, while in peat marshes, where the water table was almost stationary at about 2.5 feet, they did not penetrate to a depth of more than 18 inches. The downward penetration of the corn roots was bounded by a zone sharply defined by the flattening out of the roots within it. This zone, not more than 3 inches in thickness, lay 18 inches above and parallel to the water table.

Working Depth of the Roots of Field Crops

120. Working Depth of Roots. Weaver[31] reports studies with roots of barley to determine areas in the soil from which the larger amounts of water were drawn. Large cylinders 18 inches in diameter and 3.5 feet deep were filled with successive 6-inch layers of soil, each layer occupying the same relative position in the container that it had formerly occupied in the field. The water content of each 6-inch layer of soil was determined and then each was separated from the one above and below by thin wax seals, which prevented capillary movement of water but permitted root penetration. When the crops had matured it was found that water had been absorbed from the different 6-inch layers from the top downward in the following amounts, based on the dry weights of the soil: 20, 19, 16, 16, 14, 12 and 11 per cent. Other studies by Weaver have shown that during the period of heading and ripening the bulk of the water absorbed by barley roots was from the deeper soils where the younger portions of the roots were located, while most of the water previously had been removed from the surface layer.

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[28] Hunter, C.—"Some Observations on the Effect of Soil Aëration on Plant Growth." *Proc. Univ. Durham Phil. Soc.* Vol. 4, p. 183. 1912.

[29] Balls, W. Lawrence—*The Cotton Plant in Egypt*, p. 79. Macmillan & Company. London. 1919.

[30] Elliott, G. R. B.—"Relation between the Downward Penetration of Corn Roots and Water Level in Peat Soil." *Ecolcgy*, Vol. 5, No. 2, pp. 175-178. Apr., 1924.

[31] Weaver, John E.—*Root Development of Field Crops*, pp. 55-56. McGraw-Hill Book Co. New York. 1926.

ROOT SYSTEMS OF CROP PLANTS

While each species of plant has a particular type of root growth, the root development of individual plants within each species will often vary considerably due to differences in environment. Marked differences in the habit of growth have been noted in the root system of cereal crops due to differences in environment and variety.

121. Roots of the Corn Plant. Weaver [32] says: "Corn has a remarkably widely spreading, deeply penetrating, and profusely branching root system. A lateral spread of 3.5 feet on all sides of the plant is not uncommon even early in its development and a depth of penetration of 5 to 6 feet is usual."

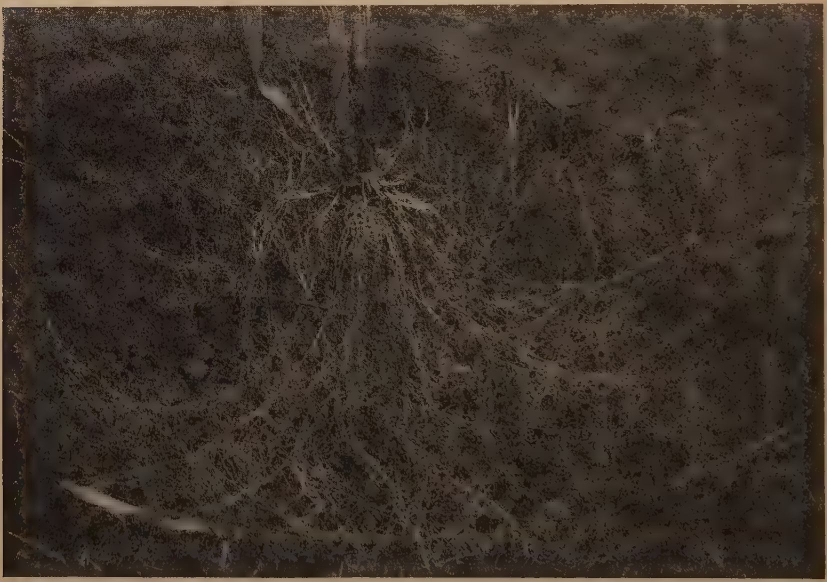

FIG. 49.—When the soil is washed away the extent and character of the root system become apparent. A portion of the root system of a single hill of corn.

Holbert [33] has shown that inbred strains of corn differ greatly in the character and extent of root development. Certain strains have such a limited and inefficient root system that they are unable satisfactorily to withstand the hot days of midsummer when the soil moisture is low, while other strains under similar conditions have shown no indication of water deficiency.

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[32] Weaver, John E.—*Root Development of Field Crops*, p. 191. McGraw-Hill Book Co. New York. 1926.

[33] Holbert, James R., and Koehler, Benjamin—"Anchorage and Extent of Corn Root Systems. *Jour. Agr. Res.*, Vol. 27, No. 2, pp. 71-78. Jan. 12, 1924.

At Manhattan, Kansas,[34] corn roots have been found at a depth of 4 to 5 feet, and at Fargo, North Dakota,[35] 3.5 to 4 feet. Under good cultivation at Madison, Wisconsin,[36] corn roots have been observed to take considerable quantities of water at a depth of 7 feet or more, though the normal growth is apparently somewhat less than this.

At Garden City, Kansas,[37] roots of corn grown in sandy loam which had 8 to 10 inches of irrigation water in the fall after plowing showed a lateral spread of 3.7 feet and a depth of 6 feet.

122. Root Development of Wheat. Weaver[38] reports that spring wheat plants 2.2 feet in height had a root penetration of 4.8 feet, and a lateral spread of 12 inches. "A vast network of rebranched laterals occupied a volume of soil extending approximately 10 inches on all sides of the plant and to a depth of 2 to 3 feet." Laterals were exceedingly abundant in the surface 2 feet of soil. Few of these exceeded a length of 4 inches and in the second foot most of the branches were less than 1 inch in length. In the lower soil areas most of the laterals were very short and unbranched.

The absorbing area of the roots of winter wheat plants, exclusive of root hairs, was found to be uniformly 10 to 35 per cent greater than the area of the leaves.

Hays and Boss[39] have reported that isolated clumps of spring wheat showed a root penetration of more than 4 feet with a spread of 32 inches.

Ten Eyck[40] reports roots of spring wheat in North Dakota as practically occupying the soil to a depth of 4 feet with "many main roots most of which ran almost vertically downward, sending out numerous laterals."

It is reported that on the Rothamsted[41] experimental fields in England very few roots of barley entered the soil to a depth of 6 inches, most of the roots occupying the surface 2 to 4 inches of soil.

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[34] Ten Eyck, A. M.—"The Roots of Plants." *Kans. Agr. Expt. Sta. Bul. 127.* 1904.

[35] Ten Eyck, A. M.—"Roots of Plants." *N. Dak. Agr. Expt. Sta. Bul. 36.* 1899.

[36] King, F. H.—"Natural Distribution of Roots in Field Soils." *Wis. Agr. Expt. Sta. Ann. Rpt. 9,* pp. 112-120. 1892.

[37] Miller, E. C.—"Comparative Study of the Root Systems and Leaf Areas of Corn and the Sorghums." *Jour. Agr. Res.,* Vol: 6, No. 9, pp. 311-332. May 29, 1916.

[38] Weaver, John E.—*Root Development of Field Crops,* p. 137. McGraw-Hill Book Co. New York. 1926.

[39] Hays, Willet M., and Boss, Andrew—"Wheat: Varieties, Breeding, Cultivation." *Minn. Agr. Expt. Sta. Bul. 62.* 1899.

[40] Ten Eyck, A. M.—"Roots of Plants." *N. Dak. Agr. Expt. Sta. Bul. 36.* 1899.

[41] Brenchley, Winifred E., and Jackson, Violet G.—"Root Development in Barley and Wheat under Different Conditions of Growth." *Ann. Bot.* [London]. Vol. 35, pp. 533-556. Oct., 1921.

A stronger and more vigorous root growth was observed where barnyard manure had improved the soil structure, several roots having penetrated the soil to a depth of 9 inches.

123. Root Habits of Oats. Weaver[42] from his extensive studies made the following statement regarding the root growth of oats: "Oats have a system of profusely branched fibrous roots which are very similar to those of spring wheat. The roots develop rapidly, those of the primary system reaching a depth of 6 to 8 inches by the time the second leaf begins to appear. Frequently, they are accompanied at this time by 3 or 4 roots of the secondary system. In moist, open soils, during favorable seasons, they may extend into the fourth foot by the end of 60 days. . . . A lateral spread of 6 to 11 inches, a working depth of 2.5 feet, and a maximum depth of 4 to 5 feet are usual."

124. Root Habits of Barley. Weaver[43] makes the following statement regarding the root growth of barley: "Barley, when grown in rich deep soil, has a root habit very similar to that of spring wheat and oats; the fineness of the roots, degree of branching, and lateral spread often being intermediate."

125. Root Habits of Cotton. Balls[44] dug up the root system of a plant belonging to one of the Egyptian varieties and found a tap root penetrating the soil to a depth of about 7 feet 4 inches, where it was checked by a water-saturated soil. He found that whenever a tap root approached soil saturated with water it ceased its downward penetration.

King[45] traced the tap root of a plant of the Pima Egyptian variety grown in Arizona under irrigation to a depth of 10 feet 8 inches.

Brown and Tate,[46] cited by Brown, dug up the roots of a mature plant of the Express variety of cotton and found that beginning at a depth of 5 inches, 21 lateral roots branched from the main root in a space of about 10 inches, the laterals radiating outward and slightly downward. There had been no rain after the last of May. Branches from the main large lateral roots, in general, were the roots which penetrated deeply. The branches given off from these laterals branched and rebranched until there was a block of soil more than 8 feet in diameter and 2.5 feet in thickness ramified throughout with fine, threadlike roots.

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[42] Weaver, John E.—*Root Development of Field Crops*, p. 174. McGraw-Hill Book Co. New York. 1926.

[43] *Ibid.*, p. 179.

[44] Balls, W. Lawrence—*The Cotton Plant in Egypt*, p. 79. Macmillan & Co. London. 1919.

[45] King, C. J.—"Water Stress Behavior of Pima Cotton in Arizona." *U. S. Dept. Agr. Dept. Bul. No. 1018.* 1922.

[46] Brown, H. B.—*Cotton*, p. 81. McGraw-Hill Book Co. New York. 1927.

Collings and Warner[47] made studies on cotton grown in rows 3 feet apart with plants 6 to 12 inches in the row with 600 pounds of 10-4-2 fertilizer drilled in 3 inches below the surface before the cotton was planted. In no case did they observe a greater development of roots in the neighborhood of the fertilizer.

126. Root Habits of Other Crop Plants. *Sorghum.* The root habits of sorghum are quite similar to those of corn, but the roots are finer and more fibrous and they often have twice as many branches as corn in a similar stage of growth.

The sugar beet. The sugar beet has a strong, fleshy tap root which usually penetrates the soil to a depth of 5 to 6 feet. Lateral roots extend out from 6 inches to 18 inches, with the greater extension in the lower soil area.

Alfalfa. This plant has a strong tap root which often reaches a depth of from 5 to 6 feet the first year, 10 to 12 feet the second year and, under the best environmental conditions, may ultimately extend to a depth of 20 feet or more. The tap root development is almost always the most prominent part of the root system, though in individual plants the main root may divide or there may be considerable lateral growth in the surface 12 inches. These lateral roots are not usually abundant and they turn downward rather than spread laterally.

Red clover. The root of red clover frequently extends to a depth of from 4 to 6 feet and may ultimately reach a depth of 8 to 9 feet. Numerous strong branches arise especially in the first foot. These spread usually 12 to 18 inches and turn downward.

Biennial sweet clover. This legume develops a strong, deep, fleshy tap root. Many strong laterals are usually developed which penetrate deeply into the soil. The tap root will often extend to a depth of 5 to 8 feet. The root of a mature plant may be from 1 to 1.5 inches in diameter although this is not to be expected in an ordinary field stand.

Roots of Various Crop Plants Compared

127. Crop Roots Compared in Nebraska. Weaver, Jean, and Crist[48] working with oats, wheat, barley, corn, and potatoes in southeastern Nebraska found that the development of the root kept pace with the development of the tops. They report the depth and lateral spread of root growth of these crops in Table *127a.*

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[47] Collings, G. H., and Warner, J. D.—"Root Development of Cotton on Cecil Sandy Loam during 1926." *Jour. Amer. Soc. Agron.*, Vol. 19, No. 9, p. 839. Sept., 1927.

[48] Weaver, John E., *et al.*—"Development and Activities of Roots of Crop Plants." p. 31. *Carnegie Inst. Wash. Pub. No. 316.* 1922.

127a. Depth and spread of roots of crop plants in southeastern Nebraska. Weaver et al.

	Age of Plant (days)	Average Height (feet)	Stage of Maturity	Maximum Depth of Roots (feet)	Maximum Lateral Spread of Roots (feet)
Early oats	92	3.0	Half ripe	6.7	1.4
Swedish Select	93	3.0	Hard dough	6.8	1.3
Durum wheat	95	2.5	Hard dough	7.4	1.2
Marquis wheat	93	2.7	Hard dough	6.7	1.3
Barley	84	2.3	Hard dough	6.3	1.3
Corn	116	8.5	Husks drying	8.2	4.0
Potatoes	94	2.3	⅓ leaves dead	4.7	2.1

Oats made a more extensive root growth than wheat. At the end of the experimental period, soils in which oats were grown had 30 per cent less water than the wheat soil and 35 per cent less than the barley soil.

Weaver[49] from his extensive studies with field crops reports the depth and lateral spread of roots as indicated in Table *127b*.

127b. Type of root and representative depth and spread of root of a number of field crops; extracted from summaries. Weaver.

Name of Crop	Type of Root System	Working Depth (feet)	Depth of Root System (feet)	Lateral Spread on All Sides (inches)
Spring wheat	Fibrous	3	4 to 5	6 to 9
Winter wheat	Fibrous	3.8	5 to 7	6 to 9
Rye	Fibrous	4	5	6 to 10
Oats	Fibrous	2.5	4 to 5	6 to 11
Barley	Fibrous	3.2	4.5 to 6.5	6 to 12
Corn	Fibrous	3.5	5 to 6	42
Sorghum	Fibrous	3.5	4.5 to 6	36
Sugar beet	Tap root	3.5	5 to 6	6 to 18
Alfalfa	Tap root	4	15 to 20	24
Brome grass	Fibrous	2.2	2 to 3	24
Orchard grass	Fibrous	2.3	3.5	18
Meadow fescue	Fibrous	3	4	3 to 6
Blue grass	Fibrous	2	5 to 7	12 to 18
Red top	Fibrous	2	2	9
Reed Canary grass	Fibrous	1.2	2	15
Timothy	Fibrous	1.2	2	12
Red clover	Tap root		5	12 to 18
White clover	Tap root		5	12 to 18
White sweet clover	Tap root		5 to 8	24 to 60
Potatoes	Tap root		2 to 3	12 to 24
Sunflower	Tap root	3.0	5 to 9	24 to 60

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[49] Weaver, John E.—*Root Development of Field Crops.* McGraw-Hill Book Co. New York. 1926.

128. Root Comparisons in Kansas. Ten Eyck reports observations in Kansas[50] when corn roots reached a depth of 4 to 5 feet; oats, barley, and wheat, 4 feet; big bluestem grass 5½ feet; brome grass and cowpeas, 4 feet; and bluegrass mostly in upper 6 inches, a few roots penetrating beyond 18 inches.

Georgeson and Payne[51] studied the roots of milo, kafir, corn, and soybeans under comparable conditions. The height of plants, greatest depth of root growth, and lateral spread (length of side root) are recorded in Table *128a.*

128a. Height of plant and depth and spread of roots of different plants, all in feet. Kansas.

CROP	HEIGHT OF PLANT	GREATEST DEPTH OF ROOTS	GREATEST LATERAL SPREAD OF ROOTS
White milo	4.5	3.25	6.0
Yellow milo	5.5	4.00	6.0
Red kafir	5.5	4.00	5.0
White kafir	5.0	4.00	4.0
Corn	9.0	3.67	5.5
Soybeans	2.5	2.83	3.0
Orange sorghum	6.0	3.5	6.0

129. Root Comparisons in Minnesota. Hays[52] determined the depth of root growth at the end of 5 months of 5 different legumes growing on a rich drift soil. The height of plant, as well as the depth of root, is given when the plant was 5 months old.

129a. Height of plant and depth of root penetration in inches. Minnesota.

CROP	HEIGHT OF PLANT	DEPTH OF ROOTS
Red clover	12	68
Mammoth clover	7	57
Alsike clover	12	30
White clover	5	24
Alfalfa	16	78

130. Root Comparisons in Utah. Sanborn[53] studied the distribution of the roots of crop plants in the soil by taking successive areas 2 feet square and 1 inch deep from the surface downward. The layer of soil in which the greatest amount of root growth was found indicates somewhat the more important feeding areas of the plant.

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[50] Ten Eyck, A. M.—"The Roots of Plants." *Kans. Agr. Expt. Sta. Bul. 127.* 1904.

[51] Georgeson, C. C., and Payne, J. E.—"Investigations of the Root Development of Some Forage Plants." *Kans. Agr. Expt. Sta. Bul. 75*, pp. 212-222. 1897.

[52] Hays, Willet M.—"Roots of Clovers." *Minn. Univ. Bd. Regents Bien. Rpt. 5*, sup. 1, pp. 188-198. 1888.

[53] Sanborn, J. W.—"Roots and Plants of Farm Crops." *Utah Agr. Expt. Sta. Bul. 32.* 1894.

130a. Root distribution of various crops. Sanborn.

Crop	Depth at Which Greatest Weight Was Found—Inches	Range Including 75 Per Cent of Roots or Over—Inches
Oats	3	2 to 4
Clover, 4-yr.-old	2	1 to 4
Corn not cultivated	4	1 to 5
Corn cultivated	4	1 to 6
Potatoes	7	7 to 12
Timothy	1	1 to 3
Barley	3	1 to 5
Wheat	4	1 to 5

131. Root Comparisons in Russia. Rotmistrov[54] studied the roots of various crops under field conditions in Russia, securing somewhat different results than those reported for the United States. It is apparent that quite different results in the depth of root growth and lateral spread may be expected in different types of soil.

131a. Depth of penetration and lateral spread of roots of various crops. Rotmistrov.

Crop	Depth of Penetration (Inches)	Lateral Spread (Inches)
Corn	44	52
Potato	24	39
Sorghum (black)	43	31
Sorghum (yellow)	41	43
Millet (German)	41	36
Cotton	37	41
Rye	46	24
Wheat	40	36
Beet	57	43

132. Ratio of Tops to Roots. The ratio of top growth to root growth in plants may be expected to vary considerably under different soil and climatic conditions. (222)

Harris[55] found that the length and weight of roots of wheat seedlings were proportionately greater in dilute than in concentrated soil extracts.

Corn, wheat, and peas grown in sand supplied with different amounts of water showed a proportionately greater root growth in the drier soils.

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[54] Rotmistrov, V. G.—"Root Systems of Cultivated Plants of One Year's Growth." *Odessa Rpt.* (English) Cited by Miller, Edwin C., "Roots of Agricultural Plants." *Jour. Amer. Soc. Agron.*, Vol. 8, No. 3, p. 153. May-June, 1916.

[55] Harris, Frank S.—"The Effect of Soil Moisture, Plant Food, and Age on the Ratio of Tops to Roots in Plants." *Jour. Amer. Soc. Agron.*, Vol. 6, No. 2, pp. 65-75, Mar.-Apr., 1914.

King[56] found the ratio of top to root for a number of plants to be as follows: oats, 2.2 to 1; barley, 3.3 to 1; clover, 4 to 1; corn, 6.8 to 1.

Schulze[57] washed out the roots of various crops grown in compartments 60 cms. square and 2 meters deep. His results are shown in Table *132a.*

132a. Weight of tops, of roots and the ratio of tops to roots, of various plants. Schulze.

CROP	STAGE	WEIGHT OF TOPS	WEIGHT OF ROOTS	POUNDS TOPS TO ONE POUND ROOTS
Rye	Before heading	3.68	1.79	2.0
Rye	Bloom	28.80	6.08	4.7
Rye	Milk	46.17	4.66	9.9
Wheat	Before heading	3.99	1.88	2.1
Wheat	Booting	32.48	9.01	3.6
Wheat	Milk	46.50	4.90	9.5
Wheat	Ripe	31.44	2.89	10.8
Barley	Ripe	27.82	2.05	13.5
Oats	Ripe	45.40	4.09	11.1
Vetch	Bloom	14.00	2.20	6.3
Potato		36.30	15.10	2.4

STUDY QUESTIONS ON CHAPTER V

1. What are the functions of roots? What portion of the animal body may be said to correspond to the root system of a plant?
2. How does the type of root system of a plant influence the ability of the plant to thrive in competition?
3. Why is it possible for a root to take in water at or near the root tip and not let it escape at other places along its length?
4. Why do roots continue to branch and push into new areas? Why are new root hairs continually being formed?
5. How do roots secure the necessary materials for respiration and under what conditions is this process interfered with?
6. How do you account for the solvent action of roots?
7. Why do certain crop plants often fail to make a satisfactory growth when produced on the same soil through several seasons?
8. I have two fields of corn; on one the roots are all near the surface and very finely branched, while on the other the roots extend deeply into the

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[56] King, W. H.—"Natural Distribution of Roots in Field Soils." *Wis. Agr. Expt. Sta. Ann. Rpt. 9*, p. 119. 1892.

[57] Schulze, B.—"Studien über die Bewurzelung unserer Kultur pflanzen." *Festschrift 50 Jubiläum Agr. Chem. Versuchs und kontroll. Sta. Breslau*, pp. 67-95. Cited by Miller, Edwin C., "Root Systems of Agricultural Plants." *Jour. Amer. Soc. Agron.*, Vol. 8, No. 3, p. 153. May-June, 1916.

soil but do not branch extensively. What conditions may account for these differences?

9. Why do plants generally grow better above or near a tile in a newly tiled field than on other parts of the field?
10. What are the major factors affecting the root growth and the branching of the roots?
11. In what sections are the roots of plants likely to be extensive? Limited? Why?
12. Make two groups of crop plants, the first shallow-rooted and the second deep-rooted. What characteristics are common to the plants in each group?

APPLICATION ASSIGNMENTS ON CHAPTER V

1. You are growing corn in a region where rainfall is scanty in midsummer. The crop can better withstand this condition if deep-rooted. What can you do to induce deep-root development?
2. You are growing corn in a region of abundant rainfall. Having in mind root development, what application of fertilizer will you make and how will you apply it? What change would you make if farming in an area of scanty rainfall?

CHAPTER VI

WATER IN RELATION TO PLANT GROWTH

One of the most important factors affecting plant growth is the water supply. Crop yields are quite definitely associated with precipitation though yield per acre is likely to be much more closely related to the seasonal than to the annual rainfall. The precipitation must be absorbed by the soil and much of it retained for some considerable time if it is to be of any great use to the plant.

THE SOURCE OF SOIL WATER

133. Rain from Plant Evaporation. Rains are recognized as the direct source of most of the water used by our crops. The original source of most of this water which falls as rain has been credited by Zon [1] to the evaporation from the growing plants themselves. He estimates the water vapor (clouds) from which land precipitation comes at 26,868 cubic miles, of which 20,870 come from the land areas, the bulk of the water evaporated from the ocean falling again into the ocean.

Kiesselbach [2] has estimated the evaporation from corn leaves (both surfaces) as being 32 per cent that of an equal area of free water surface. An average acre of corn has approximately 2 acres of leaves or 4 acres of leaf surface. The evaporation from an acre of Nebraska corn might be expected to be about two-thirds that from a body of water 1 acre in area. Forests are capable of transpiring far more water than would evaporate from an equal area of water surface.

ANNUAL RAINFALL, TYPES OF FARMING, AND CROP YIELDS

134. Rainfall and Type of Farming. In an article on "Weather and Agriculture" in the 1924 *Agricultural Yearbook* [3] the authors outline some of the cropping systems that are best suited to certain amounts of rainfall. The effect of the amount of rainfall as related to types of farming is limited by variations in temperature and perhaps by other factors. In general, our crop belt limits are the 10-inch and 20-inch rainfall lines.

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[1] Zon, Raphael—"Forests and Water in the Light of Scientific Investigations." *U. S. 62nd Cong. 2nd Session. Senate Doc. No. 469*, p. 19. U. S. Govt. Ptg. Off., Washington, D. C. 1927.

[2] Kiesselbach, T. A.—"Transpiration as a Factor in Corn Production." *Nebr. Agr. Expt. Sta. Res. Bul. 6.* 1916.

[3] Henry, A. J., *et al.*—"Weather and Agriculture." *U. S. Dept. Agr. Yearbook 1924*, pp. 457-558.

Sections receiving 10 inches of precipitation (snow or rain) or less are wholly unsuited for crop production without irrigation except where the soil and environmental conditions are especially favorable for moisture conservation. Land in these sections may be used for grazing to a limited extent, though the carrying capacity is often very low, 75 acres sometimes being required to afford pasture for one animal unit through the grazing season.

Sections receiving between 10 and 20 inches of precipitation annually can be utilized best by grazing though crops may be grown successfully. Wheat and the sorghums are probably best suited to these conditions, though in the north, corn can be grown with some degree of success. With less than 15 inches of precipitation the growing of these crops is decidedly precarious, while with over 20 inches of precipitation crops are grown with ordinary farming practices. The great cereal production areas are found in sections receiving an annual precipitation of between 20 and 40 inches (39) (48).

135. Factors Influencing Results. Rainfall may affect crop yields to different degrees and in different ways depending upon the total annual precipitation, the season of the year when it falls, the rate of fall with reference to the ability of the soil to absorb it, and the temperature which prevails.

Chilcott[4] in a study of the relations existing between crops and precipitation in the Great Plains area where crop yields are considered especially dependent on rainfall found that seasonal precipitation gives a somewhat closer relationship to crop yields than annual precipitation.

136. Annual Rainfall as a Crop Index. Chilcott says, "Not only the seasonal and monthly, but also the daily, distribution of precipitation may be more important than its annual magnitude. The annual rainfall is a very poor index to the crop yields in a region like the northern Great Plains, where the normal rainfall ranges from 15 to 20 inches per annum. The agricultural possibilities of any given locality or farm can be determined only by the experience of practical farmers."

The annual and seasonal rainfall and the yield of corn, cotton and sorghum for three seasons at San Antonio, Texas,[5] is shown in Table *136a*.

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[4] Chilcott, E. C.—"Relations between Crop Yields and Precipitation in the Great Plains Area." *U. S. Dept. Agr. Misc. Cir. 81.* 1927.

[5] Briggs, Lyman J., and Belz, J. O.—"Dry Farming in Relation to Rainfall and Evaporation." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 188*, p. 30 and p. 23. 1910.

136a. Rainfall and crop yields at San Antonio, Texas.

Year	Annual Rainfall Inches	Corn		Cotton		Sorghum	
		Seasonal Rainfall Inches	Yield Bu.	Seasonal Rainfall Inches	Yield Lbs.	Seasonal Rainfall Inches	Yield Tons
1907........	26	9.3	17.5	13.0	377	11.3	3.1
1908........	27	10.0	27.4	17.7	1096	16.4	13.0
1909........	13	4.4	9.9	9.3	640	8.2	1.9

Crops Best Suited to Limited Rainfall

137. Drouth-Resisting Crops. Sixteen years of dry farming investigations in Utah[6] indicate that for that state winter wheat is by far the most important dry-farm crop. Spring wheats are sometimes useful where winter wheat has failed to give satisfactory results. On the experimental dry-farms barley ranks next to wheat in yield, while oats have not been grown successfully.

Corn, peas, beans, and potatoes have not given good results on the dry-farms except in seasons of high spring rainfall.

Alfalfa, with an average yield of nearly a ton to the acre at Nephi, ranks highest as a dry-farm forage crop. Sweet clover, tall meadow oat grass, and brome grass give fair yields, but several factors work against their economic production. Rye makes a good forage crop for pasture especially on land not satisfactory for other purposes.

138. Plant Adaptations. There are many factors which tend to make one plant capable of growing in sections too dry for other plants. As an example of this, the root system of the cactus plant is peculiar in that it has a shallow feeding root system and a deep anchorage root system. The resistance of this plant to arid conditions results from its ability to gather water quickly coupled with its ability to prevent evaporation. **(367)**

Miller[7] reports from a comparison of dwarf milo grain sorghum, blackhull kafir, and Pride of Saline corn that the leaf area of corn was twice that of milo and one and one-half times that of kafir, while the root systems of the three were practically the same in extent though the milo and kafir had twice as many secondary roots as the corn.

Some of the morphological plant characters which are credited with modifying the evaporation from the plant and making its water requirement lower are: (1) pubescent or hairy leaves; (2) rolling of the leaves; (3) bloom on leaf and stem (white powder as in sweet sorghums); (4) number and distribution of stomata; (5) cutinized epidermal cells, corky layer and bark; (6) stomata sunken in pits; (7) smaller leaf areas; and (8) edge presentation of the leaves to the sun.

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[6] Harris, F. S., Bracken, A. F., Jensen, I. J.—"Sixteen Years of Dry-Farm Experiments in Utah." *Utah Agr. Expt. Sta. Bul. 175*, pp. 42-43. 1920.

[7] Miller, E. C.—"Comparative Study of the Root Systems and Leaf Areas of Corn and the Sorghums." *Jour. Agr. Res.*, Vol. 6, No. 9, pp. 329-330. May 29, 1916.

THE USE OF WATER BY PLANTS

139. Stomata and Water Conservation. The stomata vary in size as well as in number. Martin[8] states that 60,000 per square inch is a fair average. The variations between crops and between the two leaf surfaces of the same plant are given in Table *139a*.

139a. Number of stomata in common crop plants.

PLANT	LOWER LEAF SURFACE	UPPER LEAF SURFACE
Alfalfa	160	160
Beans	281	40
Oats	23 – 27	25 – 48
Wheat	14	33
Corn	68 – 158	52 – 94
Sunflower	325	175

While true desert plants have few stomata, crop plants grown under dry conditions ordinarily have a relatively larger number per unit of surface than those grown with plenty of moisture. Under the dry conditions the individual cells separating the stomata do not become so large, so that the stomata are closer together and more numerous in a given leaf area. Strains of drouth resistant or hardy plants have been shown to transpire faster than less hardy ones when supplied with plenty of water, but when the water supply runs low the tender plants die while the hardy ones survive. The internal structure of the cells of the drouth-hardy plant is more stable and more resistant to drying.

Duggar[9] gives data showing the effect of varying amounts of soil moisture on the number of stomata. Counts were made on the area under the microscope.

Stomata do open and close in response to light and in response to moisture, but they do not foresee dry weather coming and hence close to conserve water. The wilting of the plant results in closing the stomata, and when plenty of moisture is again present in the cells, the turgor of the cells opens them.

The ability of a plant to withstand drouth may depend somewhat upon the adjustments the plant is able to make. Some plants have the ability to go into a more or less dormant condition when the supply

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[8] Martin, John N.—*Botany with Agricultural Applications.* Second edition, pp. 248-249. John Wiley and Sons, New York. 1920.

[9] Duggar, Benjamin Minge—*Plant Physiology*, p. 92. The Macmillan Company, New York. 1911.

139b. Moisture content of the soil and its effect on the number of stomata. Duggar.

Per Cent Soil Moisture	Corn			Wheat		
	No. Leaves per Plant	Wt. of Tops	No. of Stomata	Length of Tops	Wt. of Tops	No. of Stomata
38	3.0	3.6	181	3.9	.46	103
30	3.0	3.5	130	6.4	1.09	85
20	3.0	3.4	129	4.7	.57	82
15	2.8	2.4	124	3.7	.35	81
11	2.0	1.6	107	3.7	.47	59

of water is deficient. Some have the ability to wilt and then revive later when moisture conditions become more favorable. Corn, small grains, and most grasses, when grown under dry conditions, may lose their lower leaves by firing. In this way the leaf area is cut down and the evaporation from the plant is reduced.

FACTORS WHICH INFLUENCE THE REQUIREMENT OF PLANTS

140. Water Requirement of Plants. Many experiments have been conducted to test the water requirement of plants under varying conditions of growth. Water requirement studies are usually made with plants growing in pots or other containers. The top of the pot or container is sealed except for the place where the plant enters the soil and an opening through which water is applied to the pot. The term *water requirement* has come to mean the pounds or units of water required to produce a pound, or unit, of dry matter. (Unless otherwise stated, the figures given here indicate pounds of water to produce one pound of dry matter.) This should not be confused with the amount of water required by an acre of a growing crop as this varies directly with the amount of dry matter produced by the crop, as well as the nature of the crop and other factors. While the water requirement of a particular crop may be relatively low, the crop may suffer more from drouth than one in which the water requirement is more because of a larger total production of dry matter per acre.

141. Effect of Fertility on Water Requirement. Montgomery and Kiesselbach[10] measured the effect of barnyard manure on the water requirement of corn grown on three types of soil—infertile, intermediate, and fertile. The water requirement in the case of the infertile soil was 550 pounds where no manure was applied and 350 pounds where manure was applied. For the intermediate soil the requirement was 479 pounds with no manure and 341 pounds where the manure was applied. In the case of the fertile soils, the water requirement was 392 pounds without manure and 347 pounds where the manure was applied.

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[10] Montgomery, E. G., and Kiesselbach, T. A.—"Studies in the Water Requirement of Corn." *Nebr. Agr. Expt. Sta. Bul. 128,* p. 13. 1912.

Widtsoe[11] found that he could reduce the water requirement of corn from 908 to 464 pounds by adding manure to the soil.

Harris,[12] working at the New York station, found the water requirement of wheat, when no fertilizer was used, to be 682 pounds; with complete commercial fertilizer, 533 pounds; and with the high nitrogen fertilizer, 572 pounds.

Briggs and Shantz[13] have summarized much of the literature on the effect of fertilizers on the water requirement. In practically all cases the use of commercial fertilizer reduced the water requirement of the crops with which they were used.

142. Effect of Non-Nutrient Salts on the Water Requirement of Plants. Bouyoucos[14] found that when a certain nutrient solution was used, the water requirement of wheat seedlings was 511 pounds. The water requirement was reduced to 326 pounds when sodium chloride was added and to 419 pounds when sodium sulphate was added to the nutrient solution.

Lyon and Bizzell,[15] by adding sodium sulphate as a non-nutrient salt reduced the water requirement of wheat seedlings from 690 to 332 pounds. (89)

143. The Effect of the Moisture Content of the Soil on the Water Requirement. Widtsoe and Stewart[16] found that at all periods of growth the more water available to the plant the less dry matter that it produced per unit quantity of water. With an abundant supply of water leafy plants and a vigorous growth of the underground parts are produced.

Harris,[17] grew wheat seedlings on soils with different per cents of moisture. Seedlings grown on soils with 11, 13, and 37.5 per cents required 737, 696, and 854 pounds of water, respectively.

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[11] Widtsoe, John A.—"Irrigation Investigations." *Utah Agr. Expt. Sta. Bul. 105.* 1909.

[12] Harris, Franklin S.—"Effects of Variations in Moisture Content on Certain Properties of a Soil and on the Growth of Wheat." *New York [Cornell] Agr. Expt. Sta. Bul. 352.* 1914.

[13] Briggs, Lyman J., and Shantz, H. L.—"The Water Requirement of Plants." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 285.* 1913.

[14] Bouyoucos, George J.—"Transpiration of Wheat Seedlings as Affected by Soils, by Solutions of Different Densities, and by Various Chemical Compounds." *Jour. Amer. Soc. Agron.*, Vol. 3, pp. 130-191. 1911.

[15] Lyon, T. Littleton, and Bizzell, James A.—"The Plant as an Indicator of the Relative Density of Soil Solutions." *Jour. Amer. Soc. Agron.*, Vol. 4, pp. 35-49. 1912.

[16] Widtsoe, John A., and Stewart, Robert—"Effect of Irrigation on the Growth and Composition of Plants at Different Periods of Development." *Utah Agr. Expt. Sta. Bul. 119*, p. 198. 1912.

[17] Harris, Franklin S.—"Effects of Variations in Moisture Content on Certain Properties of a Soil and on the Growth of Wheat." *New York [Cornell]. Agr. Expt. Sta. Bul. 352.* 1914.

Kiesselbach and Montgomery[18] determined the water requirement of corn grown in galvanized pots 16 inches in diameter and 3 feet deep. The non-available moisture was estimated at 12 per cent of the dry weight of the soil. The moisture content of the soil in the different containers was 38, 31, 23, 17, and 13.4 per cent. The water requirement for corn was 290, 262, 239, 229, and 252, respectively. The plants grown in the pots with 13.4 per cent moisture had a very small margin of available moisture, and the plants in these pots often wilted and their leaves rolled.

Briggs and Shantz,[19] after a careful review of investigations concerning the water requirement of various crops when grown on soils varying in moisture content, conclude that there is an increase in the water requirement of most plants when the water content of the soil approaches either the extreme-high or extreme-low point. The student of plant life may well consider the probable cause.

144. Effect of Soil Type on the Water Requirement. Briggs and Shantz also summarize the literature comparing soil types in their effect upon the water requirement of plants. There seems to be a relation between soil type and the water requirement of plants, but apparently this is due to variations in the plant food content of the soil. The water requirement will be higher in poor soil whether it be sand or clay than in a more fertile soil. Differences in soil texture alone do not seem to affect the water requirement when the plant food is equally available in the different types.

145. The Effect of Cropping on the Water Requirement. Widtsoe[20] found that corn grown following three years of fallow had a water requirement of 512, while that grown on soil continuously cropped had a requirement of 593 pounds.

Thom and Holtz[21] report that wheat following wheat had a water requirement of 518 pounds, while after fallow the water requirement was 341 pounds. In another instance, wheat after wheat had a water requirement of 487 pounds; after oats, 400 pounds; after alfalfa, 391 pounds; after corn, 360 pounds, and after clover the water requirement was 310 pounds.

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[18] Kiesselbach, T. A., and Montgomery, E. G.—"The Relation of Climatic Factors to the Water Used by the Corn Plant." *Nebr. Agr. Expt. Sta. Ann. Rpt. 24*, p. 94, 1910.

[19] Briggs, Lyman, J., and Shantz, H. L.—"Water Requirement of Plants." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 285.* 1913.

[20] Widtsoe, John A.—"Irrigation Investigations." *Utah Agr. Expt. Sta. Bul. 105.* 1909.

[21] Thom, C. C., and Holtz, H. F.—"Factors Influencing the Water Requirements of Plants." *Wash. Agr. Expt. Sta. Bul. 146.* 1917.

146. The Effect of the Age of the Plant. Thom and Holtz also report the water requirement of wheat and oats at various stages of maturity.

CROP	NO. DAYS GROWTH	WATER REQUIREMENT; POUNDS
Wheat	50	422
Wheat	90	362
Wheat	137	262
Oats	30	519
Oats	60	475
Oats	90	369

147. The Effect of Different Varieties of the Same Crop on the Water Requirement. Briggs and Shantz [22] found, from work at Akron, Colo., continued through three years, that the water requirement of 6 varieties of wheat ranged from 473 to 559 pounds; 4 varieties of barley from 502 to 578 pounds; 6 varieties of corn from 315 to 413 pounds, and 4 varieties of oats from 559 to 622 pounds of water per pound of dry material.

148. Effect of Humidity and Other Environmental Factors on Water Requirement. Kiesselbach and Montgomery [23] report that corn grown in a greenhouse with a humidity of 48 and 37, respectively, for the 12-hour night and day periods, had a water requirement of 340 pounds; while corn grown in a greenhouse with a humidity of 72 and 58 for the night and day periods had a water requirement of 191.

Briggs and Shantz [24] find that the water requirement is profoundly affected by the atmospheric condition.[25] Determinations of the water requirement made at different places during the same period with the same variety of crops give quite different results owing to differences in climatic conditions. The water requirements of different crops, as determined under widely different climatic conditions, are summarized in **149**, where it may be observed that under one condition over twice as much water was required for certain crop plants as under a different environment.

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[22] Briggs, Lyman J., and Shantz, H. L.—"Relative Water Requirement of Plants." *Jour. Agr. Res.*, Vol. 3, No. 1, pp. 1-64. Oct. 15, 1914.

[23] Kiesselbach, T. A., and Montgomery, E. G.—"Studies in Water Requirements of Corn." *Nebr. Agr. Expt. Sta. Bul. 128*, p. 15. 1912.

[24] Briggs, Lyman J., and Shantz, H. L.—"Water Requirement of Plants." *U. S. Dept. Agr. Bur. Plant Indus. Bur. Bul. 285.* 1913.

[25] Briggs, Lyman J., and Shantz, H. L.—"Relative Water Requirement of Plants." *Jour. Agr. Res.*, Vol. 3, No. 1, pp. 1-64. Oct. 15, 1914.

149. Summary of the Water Requirements of Plants.

Crop	Leather	Hellriegel	King	Briggs and Shantz	Thom and Holtz
	India	Germany	Wis.	Colo.	Wash.
Corn	337	...	271	368	231
Oats	469	376	503	597	313
Wheat	554	338	...	513	375
Barley	468	310	464	534	325
Rye	...	353	...	685	...
Clover	...	310	576	797	...
Buckwheat	...	363	...	578	...
Potatoes	...	...	385	636	...
Peas	563	273	477	788	385
Beans	...	282	...	736	484
Millet	...	...	...	310	339
Rape	...	...	...	743	...
Vetch	...	...	...	690	...
Sorghums	437	...	...	322	...
Alfalfa	...	...	...	831	...
Flax	807	...	...	905	...

Briggs and Shantz also report the water requirement of other crops and weeds as shown in Table **150.**

150. Water Requirement of Certain Crop Plants and Weeds. Briggs and Shantz.

Crop	Water Requirement	Weed	Water Requirement
1. Brome grass	1016	1. Cocklebur	432
2. Cotton	646	2. Lambs quarter	801
3. Cowpeas	576	3. Marigold	881
4. Field peas	788	4. Pigweed	297
5. Rice	710	5. Purslane	292
6. Soybeans	744	6. Ragweed	948
7. Sugar beet	397	7. Russian thistle	336
8. Sweet clover	770	8. Sunflower	744
9. Wheat grass	705	9. Tumble weed	277
10. Western wheat grass	1076		

Absorption and Storage of Soil Water

Precipitation which falls in the form of rain or snow must be absorbed and retained by the soil if it is to be of any particular use to plants.

151. Kinds of Soil Water. The water in the soil has been divided into several kinds and before going further in a discussion of the relation of water to plants it will be well to consider the characteristics of each. The terms used in designating these different kinds of water and a general description of each kind are given below.

a. Hygroscopic water is that water which will still be retained by the soil particles when the soil is air dry. This water has very little direct effect on plant growth. However, it is believed to aid in bringing the plant nutrients into solution. The force which holds this water is generally considered the mutual attraction of the surface of the soil particles and the water. A second force which is sometimes credited with holding the hygroscopic and also the capillary water is the tendency of certain soil constituents to enter into a kind of loose chemical (hydration) combination with it. Hygroscopic water is ordinarily not considered as being available for plants.

b. Capillary water is that water which, in addition to the hygroscopic water, adheres to the surfaces of the soil particles in the form of a film and is so held against the pull of gravity. It may move in any direction to a limited extent in response to differences in surface tension. The capillary capacity of a soil is the balance between the forces of surface attraction and gravity. The water used by plants is almost wholly capillary water.

c. Gravitational water is that water above capillary capacity which tends to fill the spaces between the soil particles and is free to move under gravitational pull. It is called free water because it is free to move in response to the force of gravity. There are other forces or pressures which also affect its movement.

d. The water table, water level, or *ground water line* is the top line of the free water in the soil. A hole dug in the ground would fill with seepage water approximately to the height of the water table. In some sections the water table may be as much as several hundred feet below the surface. In the prairie sections of the corn belt, it is seldom found closer to the surface than 12 feet and is usually deeper.

152. Permeability of the Surface. One of the chief factors affecting the absorption of water by the soil is the permeability of the surface. Water may enter the ground through cracks in the soil, through places where plants have opened the surface, and through the spaces between the soil particles.

Moisture enters a moist soil more readily than one which is dry. In a dry soil the films of water must form around each soil particle, while in moist soils these films are already formed.

The physical structure or granular tilth of the soil has considerable influence on its permeability. A soil in which the particles are bunched together (flocculated) is more permeable than one deflocculated or finely powdered.

McCall [26] compared the absorption of moisture by a cultivated and uncultivated plot. His results for a three-year period are given in Table *152a.*

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[26] McCall, M. A.—"The Soil Mulch in the Absorption and Retention of Moisture." *Jour. Agr. Res.*, Vol. 30, No. 9, pp. 819-831. May 1, 1925.

152a. Absorption of water by cultivated and uncultivated land, three-year average. McCall.

	Rainfall during Period	Total Gain in Soil	Gain below First Foot	Per Cent Rainfall Absorbed
Mulched	5.21	2.35	1.13	31
Unmulched ...	5.21	3.12	1.54	53

He states that the unmulched soil was superior in every instance as an absorbing agent. The mulch inhibited the absorption of water by increasing the amount of water held in the mulch. In the case of a moderate rain the mulch may take up all the moisture and none of it will penetrate deep into the soil.

153. Soil Type and Penetration. Scofield[27] has compared the penetration of water in sand, loam, and heavy clay. Soils were put into glass tubes and 3 to 4 inches of water maintained on the surface. His results are given in Table *153a.*

153a. Rate of penetration of water in sand, loam, and heavy clay; measured in inches. Scofield.

Soil	1 Hr.	6 Hrs.	24 Hrs.	11 Days	Reached 60 Inches
Sand	9.5	28	52	..	30 hrs.
Loam	8	18	36	..	36 hrs.
Heavy clay ...	2	4	6	18	....

He has reported that a soil may hold as much as 6 inches of water per foot of depth, but ordinarily its net effective storage capacity is not much above 2 inches per foot of depth. The subsoil may become saturated when it contains 5 inches or less per foot, and the addition of 1 inch of water to a saturated subsoil may raise the level of the underground water as much as 1 foot.

154. Salts and Water Absorption. Scofield also studied the effect of certain salts on the permeability of the soil to water. He found that when sodium and potassium salts predominated in the soil the soil was deflocculated and rendered impermeable. When calcium or magnesium were in excess, the soil was flocculated and permeable to water. Sodium, rather than the carbonate, is the harmful substance in black alkali. Sodium when in solution even in the presence of acids reacts with the soil causing deflocculation and thus rendering the soil impermeable to water.

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[27] Scofield, Carl S.—"The Movement of Water in Irrigated Soils." *Jour. Agr. Res.*, Vol. 27, No. 9, pp. 690-692. Mar. 1, 1924.

155. Amount of Water Held by the Soil. The moisture content of a soil is usually expressed in per cent based on the weight of water-free soil. When the pore space is entirely filled with water, the soil is said to be saturated. King[28] states that the amount of water required to saturate a clay soil or a sandy soil is identical with the pore space; that is, approximately 50 per cent for the clay and 30 to 35 per cent for the sand. The weight of a fine clay soil has been estimated at 75 to 80 pounds; common loams 80 to 90; sands 95 to 109 and peats 30 to 50 pounds per cubic foot.

Israelsen and West[29] have summarized the results secured by tests conducted on many different types of soil to determine the amount of moisture absorbed when the soil was in need of irrigation. This work indicates an absorbing capacity of from 0.5 inch per foot in sand to 2.25 inches for clay soils.

Israelsen and Winsor[30] determined the amount of water per foot to apply to gravelly loam and a Redfield sandy loam. From their investigations they conclude that 1 inch of water per foot of soil needing irrigation is ample for a single irrigation, and that if over 1.5 inches is applied at one time the excess water will likely percolate deep into the soil and be lost.

The amount of water retained by sand, a sandy loam, and a clay loam soil two and a half years and sixty days after saturation was determined by King.[31] The results are given in Table *155a*.

155a. Moisture content in sections of soil tubes certain distances from the bottom. King.

Soil	Distance from Bottom					
	3 to 6″	15 to 18″	27 to 30″	39 to 42″	63 to 66″	81 to 84″
	Per Cent Moisture					
Sand (2½ years) ...	21.0	6.4	2.6	2.1	1.7	0.2
Sandy loam (60 days)	27.7	22.2	21.7	19.4	17.0	16.2
Clay loam (60 days).	37.2	35.5	33.3	32.2	31.1	21.2

Widtsoe and McLaughlin[32] report the maximum capillary water content of a particular soil to be about 24 per cent; the optimum content, to a depth of about 8 feet, 18 per cent; the lento-capillary point about 12.75 per cent; and the hygroscopic capacity about 6 per cent. They define the lento-capillary point as the point above which the movement of moisture of capillarity will be free and below which it will be sluggish and will move only with great difficulty.

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[28] King, Franklin Hiram.—*Textbook of the Physics of Agriculture*, 6th ed., p. 124. Mrs. F. H. King. Madison, Wis. 1914

[29] Israelsen, Orson W., and West, Frank L.—"Water-holding Capacity of Irrigated Soils." *Utah Agr. Expt. Sta. Bul. 183*, pp. 23-24. 1922.

[30] Israelsen, Orson W., and Winsor, Luther M.—"Net Duty of Water in Sevier Valley." *Utah Agr. Expt. Sta. Bul. 182*, pp. 35-36. 1922.

[31] King, Franklin Hiram.—*Textbook of the Physics of Agriculture*, 6th ed., p. 134. Mrs. F. H. King. Madison, Wis. 1914.

[32] Widtsoe, J. A., and McLaughlin, W. W.—"The Movement of Water in Irrigated Soils." *Utah Agr. Expt. Sta. Bul. 115*, pp. 266-267. 1919.

156. Loss of Water by Run-off. Torrential rains are likely to result in a large run-off, while light rains may moisten the surface temporarily but be lost by evaporation. Duley and Miller[33] report that more erosion was caused at Columbia, Missouri by one rain of 2.18 inches on April 25, 1923, than occurred during the entire preceding year. Israelsen and Winsor[34] report that run-off varied from 9 per cent of the water applied in a 2-inch irrigation to a 28 per cent loss in an 8-inch application. The run-off from alfalfa was smaller than from sugar beets.

DISTRIBUTION OF MOISTURE IN THE SOIL

157. Penetration of Rainfall. Allowing a few days after heavy rains for drainage, samples of sandy loam, clay loam, and of a soil rich in humus were taken by King[35] to a depth of 1, 2, and 3 feet. The results are given for each soil in Table *157a.*

157a. Per-cent of moisture found in various soils soon after heavy rains. King.

FOOT OF SOIL	KIND OF SOIL		
	Sandy Loam	Clay Loam	Humus Soil
First foot	17.65 per cent	22.67 per cent	44.72 per cent
Second foot	14.59 " "	19.78 " "	31.24 " "
Third foot	10.67 " "	18.16 " "	21.29 " "

The soils tested were field soils undisturbed except for the sampling.

Stewart[36] reports that the penetration of moisture on cultivated corn plots 24 hours after a 0.58 inch rain was between 12 and 18 inches in medium sand and 6 inches in fine sand and sandy loam. Eight days later the effect of the rain had disappeared in the medium and fine sand but was still evident at a depth of 18 to 30 inches in the sandy loam.

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[33] Duley, F. L., and Miller, M. F.—"Erosion and Surface Run-off under Different Soil Conditions." *Mo. Agr. Expt. Sta. Res. Bul. 63.* 1923.

[34] Israelsen, Orson W., and Winsor, Luther M.—"Net Duty of Water in Sevier Valley." *Utah Agr. Expt. Sta. Bul. 182*, pp. 35-36. 1922.

[35] King, Franklin Hiram.—*Textbook of the Physics of Agriculture*, 6th ed., p. 131. Mrs. F. H. King. Madison, Wis. 1914.

[36] Stewart, H. W.—"A Study of Some of the Factors Affecting the Supply of Moisture to Crops in Sandy Soils." *Soil Sci.*, Vol. 21, p. 197. 1926.

King[37] protected an area of soil from rain and snow from October 18 until the following April. The moisture content is indicated in Table *157b*.

157b. Per cent moisture content of soil protected from rain and snow compared with that not protected. King.

	INCHES BELOW THE SURFACE					
	6	12	24	36	48	60
Oct. 18, both areas	3.4	4.7	11.9	8.1	4.5	4.9
April 14, covered area ..	2.5	4.1	8.1	4.4	4.2	6.0
April 14, area not covered	21.0	19.5	17.4	7.6	5.5	5.0

Widtsoe and McLaughlin,[38] working with an irrigated soil described as very deep and very uniform in physical and chemical composition, observed that with a given condition the distribution of water is always the same. The soil water content, determined soon after irrigation, was invariably largest near the surface and decreased as the depth increased.

158. Crop Roots and Distribution. Rotmistrov[39] finds that when water has percolated beyond a depth of 16 to 18 inches in a clay soil it returns to the surface only by means of the roots of plants. Working with a fallow soil in southern Russia in which the water table is over 100 feet below the surface he found a permanently moist layer of subsoil extending from 4.5 to 5.5 feet below the surface down to the water table. On old plowed fields, waste land occupied by weeds, the moist layer was first encountered at 14 to 30 feet. Above this layer to within 5 feet of the surface the soil was found to be moist or dry depending upon whether the land was in crops or fallow. From the surface down to the 5-foot depth the soil became moist every year, the plant roots utilizing this moisture during the season.

Somewhat similar evidence has been presented on the distribution of water in dry sections in this country. Determinations made by the Montana station at Havre, Montana, show that a moist layer of soil underlaid and overlaid by relatively dry soil has been in place, with no appreciable movement of water in it, for a period of approximately ten years. The layer of moist soil is the result of a season of unusually heavy rains on a fallow. The excessive rainfall in that year permitted the absorption of larger amounts of water than usual, wetting the soil down to a considerably greater depth than crop roots penetrate. Crops alternating with fallow since that time have not been able to reach and use this water, since the rainfall in the period following 1915 has never again been sufficient to moisten the soil to the top of this moist area.

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[37] King, F. H.—"Soil Water." *Wis. Agr. Expt. Sta. Ann. Rpt.* 7, p. 144. 1890.

[38] Widtsoe, J. A., and McLaughlin, W. W.—"The Movement of Water in Irrigated Soils." *Utah Agr. Expt. Sta. Bul. 115*, pp. 195-268. 1912.

[39] Rotmistrov, V. G.—"The Nature of Drought according to the Evidence of the Odessa Experimental Field." 1913. Odessa. Cited by Weaver, John E. —*Root Development of Field Crops.*

159. Source of Water and Distribution. The work of Briggs[40] indicates that the final distribution leaves the most moisture nearest the source of supply and the least farthest away. He believes this distribution to be due to the differences in the curvatures of the soil moisture films. The resistance of this film to a tangential shearing stress prevents an excessive thinning of the film, thereby checking the tendency for an equal distribution of water applied at a given point.

Other workers including Loughridge, Widtsoe, McLaughlin, Briggs, and Lapham have shown that the larger amounts of soil moisture are found nearest the source of supply no matter in what direction the movement takes place.

Movement of Moisture in the Soil

There has been a tendency in the past to assume that the water is continually coming from the water table to the surface or to the root zone of crops. A great deal of investigational work has been done on the relative distances that water will move above a water table and the effect of different types of soil on this movement.

160. Depth of Water Table and Surface Evaporation. King[41] found that 588 tons of water per acre were lost from the soil in 100 days when the water table was maintained at 11 inches below the surface in the case of black marsh soil and 741.5 tons in the case of a sandy loam soil, while a virgin clay loam lost 2,414 tons under the same conditions.

Ridgaway[42] found that when the water table was maintained at 6, 12, 18, and 22 inches below the surface the losses were 95, 70, 45, and 35 per cent, respectively, of the evaporation from a free water surface.

Alway[43] grew plants in cylinders 6 feet long. He concludes that the loss of water from the subsoil of dry lands under crops seems to take place almost entirely through the transpiration from plants. In the absence of plants the loss of water from the subsoil is small.

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[40] Briggs, Lyman J.—"The Movement and Retention of Water in Soils." *U. S. Dept. Agr. Yearbook 1898*, pp. 399-404.

[41] King, Franklin Hiram.—*Textbook of the Physics of Agriculture*, 6th ed., p. 186. Mrs. F. H. King. Madison, Wis. 1914.

[42] Ridgaway, C. B.—"Experiments in Evaporation." *Wyo. Agr. Expt. Sta. Bul. 52*, pp. 43-55. 1902.

[43] Alway, F. J.—"Studies on the Relation of the Nonavailable Water of the Soil to the Hygroscopic Coefficient." *Nebr. Agr. Expt. Sta. Res. Bul. 3.* 1913.

King[44] also tested the capillary rise of water in coarse sand. This sand was put in an apparatus arranged so that the exposed surface could be adjusted at different heights above the water table. When the column was 6.75 inches above the water table, water was raised at the rate of 44 inches per 24 hours. When the height was increased to 11.75 inches, no water was raised to the surface.

Shaw and Smith[45] determined the capillary rise of water in tubes 4, 6, 8, and 10 feet long and 8 inches in diameter filled with sandy loam and Yolo loam soils. These were run in duplicate at Berkeley and again at Davis, California. The tubes were filled with the soil and settled and water added to the top until drainage occurred below. The water evaporated from the surface, as shown in Table *160a*, gives a measure of the amount raised by capillarity from a wet soil with free water at various distances below the surface.

160a. Inches of water evaporated in one month from the surface of columns of soil of varying heights above free water. California.

HEIGHT ABOVE FREE WATER	INCHES OF WATER	
	Berkeley	Davis
4 ft.	1.57	3.50
4 ft.	2.10	3.69
6 ft.	.54	1.85
6 ft.	.70	1.99
8 ft.	.00	.97
8 ft.	.15	1.03
10 ft.	.00	.16
10 ft.	.00	.17

161. Capillary Rise. Keen[46] tested the capillary rise of water, using cylinders 6 feet deep and 2.5 feet in diameter set down in the earth with the tops level with the surface.

He believes that the results indicate that under field conditions moisture available to crops is not markedly replenished from below.

Wollney[47] claims that capillarity in soils ceases when the diameter of the particles is more than 2 mm., and that it varies with smaller particles in proportion to their fineness,—the finer the particles the greater the lifting power but the slower the movement. He concludes that loss of water by evaporation from water underneath the soil surface decreases as the distance between the surface of the water and the surface of the soil increases. Capillary height for clay may exceed 2 meters, while for a medium sand it is generally less than 0.4 meter.

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[44] King, Franklin Hiram—*Textbook of the Physics of Agriculture, 6th ed.*, p. 167. Mrs. F. H. King. Madison, Wis. 1914.

[45] Shaw, Charles F., and Smith, Alfred—"Maximum Height of Capillary Rise Starting with Soil at Capillary Saturation." *Hilgardia*, Vol. 2, No. 11, pp. 399–410. 1927.

[46] Keen, B. A.—"Agricultural Meteorological Work at Rothamsted." *Jour. Min. Agr.* [*Gt. Brit.*], Vol. 33, No. 3, pp. 215–16. June, 1926.

[47] Wollney, Ewald—"The Physical Properties of the Soil." *Expt. Sta. Rec.*, Vol. 6, Part 2, pp. 853–863, 1895.

Willard and Humbert[48] have reported from the New Mexico station that the maximum height that moisture will rise in soil-filled tubes set in water was: in a sandy soil, 32 inches, and in a clay adobe soil, 50.5 inches. They also found that there was but very little movement of moisture from a wet into a dry soil, although moisture did move 30 inches in one case from a wet soil to the roots of wheat plants.

Garola[49] studying the rise of capillary water in soils, found that, in sand, water rose quickly to a height of 55 cm. after 3 days and remained there. In silts the rise was slower but continued for a week and reached a height of 80 cm. In silicious clay the rise was considerably slower as it took 191 days for the water to reach a height of 1 meter.

In the case of one soil Tulaikow[50] observed a rise of 315 cm. in 513 days in a particular soil with which he worked, and the maximum had not been reached as yet; while with 3 finer textured soils the rise at the end of 1.5 years had become stationary at 60 to 70 cm.

McCall[51] found that a soil kept mulched by placing a fine, dry layer on the surface lost 0.73 inches of water from the first foot, while an unmulched soil lost 1.52 inches of water during the summer as an average for 3 years. In the second foot of soil the loss was 0.02 and 0.46 inches, respectively, and 0.00 and 0.04 inches for the third foot. He believes that this loss indicates a moisture movement upward without a water table.

162. Upward, Horizontal, and Downward Movement. In another test Shaw and Smith arranged soil in tubes extending upward, horizontally, and downward from free water. The water penetrated the soil in 35 days to a distance of 30 inches vertically, 76 inches horizontally, and 162 inches downward. At the end of this period vertical movement had practically stopped, horizontal movement was intermediate, and downward movement was still rapid when compared with the vertical movement even in the first 5 days.

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[48] Willard, R. E., and Humbert, E. P.—"Soil Moisture." *N. Mex. Agr. Expt. Sta. Bul. 86.* 1913.

[49] Garola, C. V.—"Etudes sur L'Ascension Capillaire dans les Sols." *Ann. Sci. Agron. Franç. et Étrang.* Vol. 42, pp. 1-32. 1925.

[50] Tulaikow, N.—Einige Laboratoriums Versuche über die Kapillarität der Boden (Abstract) in *Zhur. Opuitn. Agron.* (*Russ. Jour. Exp. Landw.*) t. 8. Kniga 6, pp. 664-666, 1907. Quoted by Weaver, John E.—*Root Development of Crop Plants.*

[51] McCall, M. A.—"The Soil Mulch in the Absorption and Retention of Moisture." *Jour. Agr. Res.*, Vol. 30, No. 9, p. 819. 1925.

The moisture content of a soil at different depths, determined at intervals through 17 months, as reported from Nebraska,[52] is given in Table *162a*. The water table was subject to fluctuations varying from 17 to 20 feet below the surface. These data are of more than usual interest.

162a. Distribution of moisture in a soil, at intervals, through a period of seventeen months. Nebraska.

DEPTH, FEET	JUNE 1910	JUNE 1911	APRIL 1912	NOV. 1912	APRIL 1913
1	8.5	8.5	21.0	11.6	21.6
2	8.2	8.5	15.0	8.7	17.3
3	8.2	8.4	8.4	8.2	16.5
4	8.0	8.7	8.4	8.1	9.1
[a]	[a]	[a]	[a]	[a]	[a]
9	8.9	9.1	10.1	9.4	9.7
10	10.6	9.7	13.7	11.6	14.1
11	10.3	9.8	12.2	11.3	12.3
12	10.8	9.6	12.7	10.1	12.1
13	10.8	15.0	15.7	11.2	16.9
14	12.8	17.2	21.3	14.4	22.2
15	21.0	21.0	24.8	20.5	27.6

[a] Samples 5 to 8 feet practically uniform throughout the period at from 8 to 9 per cent.

163. Plant Roots and Soil Moisture Content. Barker[53] determined the moisture content of a soil at 1 foot intervals to a depth of 6 feet. The average result for 3 years under small grains, alfalfa, corn, and fallow or summer tillage is given for each crop during June and July in Table *163a*.

163a. Moisture content of the soil under different crops; three-year average. Nebraska.

DEPTH	SMALL GRAINS		ALFALFA		CORN		SUMMER TILLAGE	
	June	July	June	July	June	July	June	July
1 ft. ...	19.1	17.6	20.9	22.0	28.5	23.7	26.7	24.8
2 ft. ...	19.7	19.0	25.4	21.8	28.3	27.4	28.0	25.9
3 ft. ...	21.1	19.5	25.0	19.9	23.6	25.7	23.9	23.6
4 ft. ...	19.7	19.0	20.9	17.4	22.3	22.8	23.7	25.0
5 ft. ...	24.7	22.6	20.7	17.9	23.5	23.7	26.9	25.9
6 ft. ...	25.9	23.0	20.4	18.2	26.2	25.0	25.9	26.1

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[52] Burr, W. W.—"The Storage and Use of Soil Moisture." *Nebr. Agr. Expt. Stat. Res. Bul. 5*, p. 75. 1914.

[53] Barker, P. B.—"Moisture Content of Field Soils under Different Treatments." *Nebr. Agr. Exp. Stat. Ann. Rpt. 25*, p. 107. 1911.

Miller[54] reports a study of the root systems of corn, kafir, and milo in which he found that the root systems of these crops had penetrated through the sixth foot of soil by August. Determinations of the soil moisture at different depths led him to conclude that there was little, if any, depletion of the soil moisture below the depth to which roots penetrated.

Alway and McDole[55] state that when soils are thoroughly moistened and then protected from losses by evaporation they lose water by downward movement. The downward movement will continue until the ratio of moisture content to hygroscopic coefficient lies between 1.8 and 2.5. When this downward percolation ceases, the soil contains only capillary and hygroscopic moisture. They further state that the moisture in the subsoil is able to move upward only slowly and such a short distance in a single season that it will at most be of no practical benefit to an annual crop.

Shaw[56] studied the moisture capacity of soils and found that, when water is added to a body of uniform soil and allowed to percolate downward through the soil mass, a condition of distribution will be reached at which the moisture content at any depth will be approximately the same except in the lowest five or six inches of wetted soil where there is a very rapid decrease in the moisture content.

Alway[57] reports field studies in Saskatchewan in 1904 and 1905 from which the conclusion is reached that in semi-arid regions the roots of plants go to the stored water in the subsoil instead of the water being elevated to the surface by capillarity and that but comparatively little water which has once passed below the first foot is lost by evaporation.

Kiesselbach[58] *et al* report that alfalfa grows well for 4 or 5 years when first seeded on certain Nebraska soils, then yields rapidly decline due to the depletion of available subsoil moisture. The alfalfa drew upon the subsoil moisture to a depth of 33 feet in a 6-year-old meadow and 25 feet in a 2-year-old meadow. After once having the subsoil moisture exhausted, it is replaced very slowly under ordinary cropping. During 15 years of cropping after alfalfa but little water had entered the soil below 7 feet. The statement is made that after 6 years cropping to alfalfa it would require 225 years under crop rotation to restore the subsoil moisture.

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[54] Miller, Edwin C.—"Comparative Study of the Root Systems and Leaf Areas of Corn and the Sorghums." *Jour. Agr. Res.*, Vol. 6, No. 9, pp. 311-332. 1916.

[55] Alway, Frederick J., and McDole, Guy R.—"Relation of the Water-retaining Capacity of a Soil to Its Hygroscopic Coefficient." *Jour. Agr. Res.*, Vol. 9, No. 2, pp. 68-69. Apr. 9, 1917.

[56] Shaw, Charles F.—"The Normal Moisture Capacity of Soils." *Soil Sci.*, Vol. 23, p. 303. 1927.

[57] Alway, F. J.—"Some Soil Studies in Dry-land Regions." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 130*, pp. 17-42. 1908.

[58] Kiesselbach, T. A., *et al.*—"The Significance of Subsoil Moisture in Alfalfa Production." *Jour. Amer. Soc. Agron.*, Vol. 21, No. 3, p. 241. 1929.

Very similar work is reported by Duley[59] from the Kansas Experiment Station.

Shantz[60] discusses the distribution of moisture in the soil as follows:

"In arid and semiarid regions, soil moisture has been the subject of extended investigation. In such regions moisture is the chief limiting factor and the plant growth exhausts the total available moisture almost every season. Following a rain, the surface soil becomes moist. If the soil we may consider would have a moisture equivalent of 20 per cent and a weight of say 84 pounds per cubic foot, a rainfall of 2 inches would wet it only 9 inches, if it were entirely dry. But under field conditions it would probably contain 10 per cent when dry to the plant, and a rain of 2 inches would moisten about 18 inches, if none were lost by run-off. This soil would contain about 21 per cent water. This 18-inch blanket of moist soil would remain, no water passing down and the surface gradually drying. Moisture would not pass up or down in appreciable amounts. Another rain would replace that lost by evaporation and the moist layer would be deepened until the whole surface blanket contained about 21 per cent. Under the surface moist soil the subsoil would remain permanently dry. By dry here is meant a soil with 7 to 10 per cent moisture, depending somewhat on the condition under which the moisture was reduced. In other words, no moisture can be added to this soil to make it less than about 21 per cent, and under field conditions not much more than about 21 per cent can be added.

"Above a water table, moisture rises in the soil to form the capillary fringe. In the soil considered, the top of the fringe might have about 21 per cent water; and this would increase until just above the water table the water content might be 52 per cent, while just below the water table all pore space would be filled with water. We know pretty clearly what the conditions are and the upper and lower limits of moisture content in a region where the surface is temporarily moist, the subsoil down to the capillary fringe permanently dry, and the water table at a permanent level, or, in other words, the moisture condition when the rainfall is not sufficient to moisten the soil below the reach of the plant roots. But most of the agricultural production takes place under very different conditions when the amount of rainfall is in excess of the field carrying capacity of the first few feet of soil and where moisture passes through the subsoil to the water table below, in other words, where the whole soil mass is leached and where the water is available throughout the whole depth of the soil.

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[59] Duley, F. L.—"The Effect of Alfalfa on Soil Moisture." *Jour. Amer. Soc. Agron.* Vol. 21, No. 2, p. 224. 1929.

[60] Shantz, H. L.—"Soil Moisture in Relation to the Growth of Crop Plants." *Jour. Amer. Soc. Agr.* Vol. 17, No. 11, p. 705. 1925.

"The conditions here are not well known, but there seems little reason to suppose that the field carrying capacity in the root zone

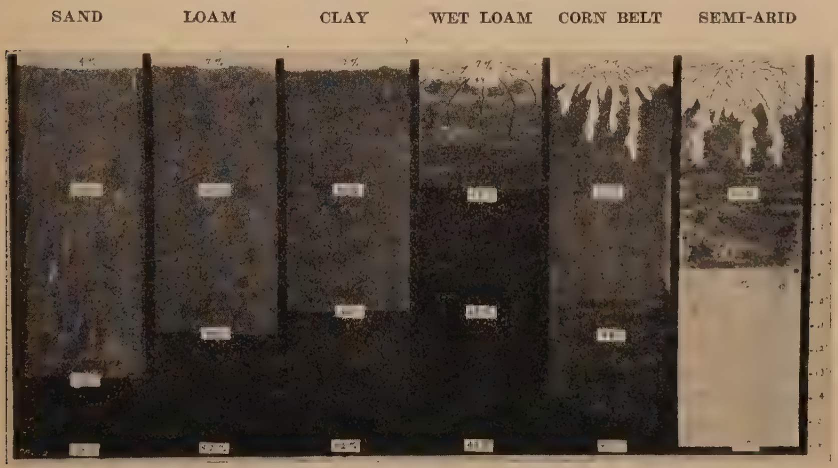

FIG. 50.—Examples of moisture distribution in soils of different types. The water table at the bottom of each soil is represented in black, at from 15 to 16 feet below the surface, except for "wet loam" which is at 6 feet (no water table shown for semi-arid soil). The water content within this area is the same as the pore space, and in the particular soils represented, varies from 38 to 52 per cent. The distance above the water table to which the "capillary fringe" extends for the different soils is shown in inches. The moisture content of the soil above the capillary fringe represents soil at its capillary capacity and is shown in per cents. *Why are the lower roots in the "wet loam" represented as surrounded by soil of high moisture content, while those in the "corn belt" and "semi-arid" soils are represented as surrounded by soil containing approximately seven percent of moisture? How is the moisture content of soils reduced below capillary capacity?*

should be higher when the subsoil is moist than when the subsoil is dry, provided the water table in the former case lies so far below that the top of the capillary fringe does not reach the root zone. The moisture content at the surface of the soil here considered should be about 21 per cent, and as we pass down remain about the same until the top of the capillary fringe is reached, unless there should be perched water tables. If the moisture in the surface soil is evaporated or absorbed by plants, there should be no movement upward to take its place. In fact, the whole mass of soil moisture should remain stationary until water is again added above, when it would move down until the moisture content had fallen to the field carrying capacity. This is probably the condition in most of the crop areas of the United States."

STUDY QUESTIONS ON CHAPTER VI

1. Where does the moisture which forms the clouds come from?
2. Outline the crop belts with reference to limits of rainfall.
3. An area in North Dakota and one in Texas receives the same rainfall. In which area is crop growth most likely to be limited by moisture deficiency? Why?
4. Explain the lack of close correlation between yield per acre and annual rainfall in the Great Plains area.
5. Group the field crops with reference to their resistance to drought. How do you account for these differences?
6. What adjustments do plants make during the growing period when the water supply becomes deficient?
7. Of two corn plants grown in the same locality, one had a water requirement of 350 and the other, of 275 pounds. How can such differences be accounted for?
8. What can be done to put a soil in condition for maximum water absorption? For maximum water retention?
9. How many inches of rainfall can a soil hold and how does this vary for different soils?
10. Starting with an oven-dry soil and gradually increasing the water content, in what order will the different types of soil water be found? Which of these are available to plants?
11. What forces move water from place to place in the soil?
12. What governs the distance that water will move?
13. In your section does water come up from below to support the growth of crop plants? Give reasons for your answer.
14. Describe the moisture changes taking place in the soil, their extent, and the normal distribution toward which these tend.

APPLICATION ASSIGNMENTS ON CHAPTER VI

1. In an extremely dry period, you observe that all leaves on your corn are rolled and the lower leaves appear to be dying. Why? What can you do? If the dry weather continues what will happen?
2. Following a period of dry weather, you lifted a plank lying on the surface of the soil in your garden and found the soil moist. The same day you tore up a granary floor and found the soil below dry. Explain the difference in the soil condition.
3. You have a field free of weeds but crusted over. The land is rolling. You expect a rain and want it to absorb all the rain possible. Will you stir the soil? Explain.

4. The crop growing on your irrigated soil has most of its roots within two feet of the surface. Most of the water in this soil area has been used. You can give an application of either three or six inches of water. Which will you use? Why?
5. In a dry farming area, you can apply barnyard manure and lower the water requirement from 300 to 250 pounds and increase the dry matter produced one-half. Will you apply manure? Why?

CHAPTER VII

THE SOIL IN RELATION TO PLANT GROWTH

The soil is the home of the plant. Plants, like children, are profoundly influenced by the "home" environment. While man is limited in his efforts to modify the environment above the surface of the soil he has considerable control over the soil environment of the plant; tilth, temperature, moisture, aeration, and the nutrients available are all more or less under his control.

164. Man vs. Nature in Soil Maintenance. It might be well to point out that in various parts of the United States and of the world there are sections where it is impossible to grow crops profitably at the present time but where at some time in the past good crops were produced. This difference is due largely to changes in the soil, the above ground environment remaining approximately the same through thousands of years. It is man—not nature who has failed and brought this ruin.

The burden of responsibility for these unproductive soils varies widely in the different sections of the country. Most farmers in all sections have the same general purpose in mind; that of getting as large a return as possible from the soil and giving only as much in return as seems absolutely necessary at the time. Differences in the fertility of the land in the corn belt, the wheat belt, and the cotton belt are often attributed to differences in the degree to which good farming is practiced. In thinking of this variation in fertility we should remember that profitable crops can be grown over a much longer period in sections having medium to heavy soil, moderate rainfall, and comparatively level land than is possible with the same efforts of man in sections having the lighter soils, more rolling land, and heavier rainfall.

The soil as the home of the plant will be considered under two general headings: (1) The general characteristics of the soil as they relate to plant growth, soil type, aeration, temperature, soil solutions, and soil fertility. (2) Factors which bring about changes in the soil; soil organisms in general and the processes of decomposition, ammonification, nitrification, and soil deterioration; lime and liming, barnyard manure, green manures and commercial fertilizers.

General Characteristics of the Soil

Soils vary in a number of characteristics and the variation in one factor may profoundly influence others as there is a very important interrelation between them.

165. Kinds of Soil. Soils are classed either as residual or as transported soils. *Residual* soils are soils formed by the disintegration of the rock and remain in place of the rock where the disintegration occurred. *Transported* soils are those which have been moved from the place of origin and they include (1) glacial drift soils, those transported by the movement of glaciers; (2) loess soils, consisting of silt, very fine sand and a little clay, moved in most cases by the wind and perhaps in some cases by water, (3) the alluvial soils which are formed in river valleys and lowlands from material carried from the higher lands; (4) marine soils; (5) lacustrine soils; and (6) colluvial soils. **(57)**

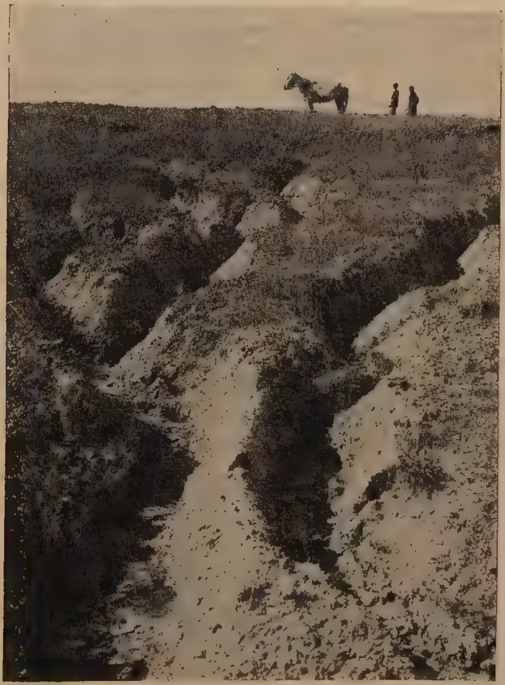

Fig. 51.—Rolling farm land improperly managed and which has leached and washed so badly that a large part of it is worthless and will not even grow wild grasses.

In general, soils are commonly spoken of as being sand, peat, loam, clay, etc. Such a division is usually based on the size of the soil particles and the amounts present of each type.

166. Soil Profile. A cross section of a soil from the surface downward usually shows an arrangement of layers including the surface or top soil and a layer or various layers designated as subsoil. The top or surface soil includes a layer which is usually 6 to 12 inches deep and in this layer is most of the nitrogen since this element of the soil is found in conjunction with or as a part of the organic matter. Phosphorus is found both in the organic matter of the surface and in a mineral form in the soil; and, although a somewhat greater proportion of this is found in the surface soil, it may be more or less abundant in the subsoil. Potassium, on the other hand, is found to increase more or less regularly with depth, the subsoil usually being richer in this element than the surface soil.

Most crops fail to grow on ordinary subsoils alone, probably due to a lack of nitrogen; although some of the legumes, particularly sweet clover when properly inoculated, may grow splendidly.

167. Soil Types and Cropping Methods. In many cases crops behave quite differently on the different types of soil, and methods of handling these crops and the effects of certain operations may be decidedly different. Weir [1] found that in Indiana the dominant soil types, as determined by the soil survey, corresponded to those recognized by farmers, given descriptive names in their management practices and in their estimates of average yields and of relative land values.

SOIL AËRATION

168. Aëration and Carbon Dioxide. The amount of space between the soil particles varies with the different types of soil. A sandy soil has approximately one-third of its volume as pore space while a clay soil has approximately one-half. This pore space may be occupied by either air or water. Plant roots in the soil and organisms of the soil are continually taking oxygen from the air of the soil and replacing it with carbon dioxide in the respiration process. The larger the soil particles the greater will be the circulation of air in the soil. Aëration is, therefore, much better in sandy soils than in the heavier types of soil when each has its optimum water content, in spite of the fact that clay and similar fine soils have a greater total volume of air.

Lau [2] determined the variations in the carbon dioxide in the soil atmosphere at various depths in a sand, a loam, and a peat soil. At a depth of 6 inches the soil atmosphere varied from 0.11 to 0.143 per cent carbon dioxide and at 24 inches 18.42 to 20.19 per cent. Air in peat soil contained the most carbon dioxide; clay was next, and sand had least. He found that in all types the soil air was richer in carbon dioxide in the summer, next in the autumn, less in spring than in autumn, and least in the winter.

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[1] Weir, W. W.—"A Study of Soil Types in Relation to Utilization and Management." *Jour. Amer. Soc. Agron.* Vol. 18, No. 12, p. 1075.

[2] Lau, Erich—Beiträge zur Kenntniss der Zusammensetzung der in Ackerboden befindlichen Luft. Doctor's Thesis, Rostock. 1906, quoted by Gainey, P. L., and Metzger, L. F., in *Jour. Agr. Res.*, Vol. 11, No. 2, p. 60. 1917.

Boussingault and Lewy[3] found the per cent of carbon dioxide in a sandy subsoil as low as one-fourth of one per cent and of a sandy soil 10 days after manuring as high as nine per cent.

169. Aëration and Drainage. Any increase in the water content of a soil is at the expense of the air content. Plants on poorly drained soil are inclined to be yellowish and stunted, and this is also characteristic of plants growing on soils deficient in nitrates. It has been suggested that the high water content of the soil has resulted in decreasing the oxygen content below that necessary for proper nitrification. When land needs drainage no other satisfactory substitute treatment can be given. **(119)**

Gainey and Metzger[4] found that the optimum moisture content of a soil for nitrification was two-thirds of the total amount of moisture that the soil would retain and that if the moisture content did not exceed this relation the aëration would be sufficient to a depth of 1 foot with any degree of compactness.

170. Clements on Aëration. Summarizing the literature on aëration of soils, Clements[5] states that the amount of carbon dioxide increases regularly with the depth below the surface and the amount of oxygen decreased correspondingly; that the organic matter of manure, when incorporated in the soil, greatly increases the carbon dioxide and decreases the oxygen; that the amount of carbon dioxide necessary to produce injury to plants varies from 2 to 20 per cent depending upon the type of plant and that such percentages are not infrequent, especially in manured and water logged soils.

Soil Temperature

171. Soil Temperature Influences Plant and Bacterial Growth. Hall[6] gives the minimum, optimum, and maximum temperature for the growth of representative crops, as shown in Table *171a*.

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[3] Boussingault, J. B., and Lewy, E.—"Mémoire sur la composition de l'air confiné dans la terre végétale." *Ann. Chim. et Phys.*, Vol. 37, p. 5. 1853.

[4] Gainey, P. L., and Metzger, L. F.—"Some Factors Affecting Nitrate-Nitrogen Accumulation in Soil." *Jour. Agr. Res.*, Vol. 11, No. 2, p. 63. Oct. 8, 1917.

[5] Clements, Frederic E.—"Aeration and Air Content." pp. 42-45. *Carnegie Inst. Pub. No. 315.* 1915.

[6] Hall, A. D.—*The Soil*, 3rd ed., p. 140. John Murray. London. 1921.

171a. Minimum, maximum and optimum temperature of soil for growth of crops. Hall.

Crop	Degrees F.		
	Minimum	Optimum	Maximum
Mustard	32.0	81.0	99.0
Barley	41.0	83.6	99.8
Wheat	41.0	83.6	108.5
Corn	49.0	92.6	115.0
Kidney beans	49.0	92.6	115.0
Melons	65.0	91.4	111.0

He also found that nitrifying bacteria cease their work below 41° and above 130° F. Their optimum temperature is about 99° F. Low temperatures, such as occur in the spring during cold spells, may be sufficiently low to check nitrate production and result in plants turning yellow.

172. Factors that Influence Soil Temperature. The chief source of heat for soils is direct radiation of heat from the sun though the soil may also receive heat from certain chemical changes, particularly the decay of organic matter. In this decay process as much heat is developed as if the material had been burned by fire but the actual effect on the temperature of the soil is slight. A small amount of heat may be conducted from the interior of the earth to the surface.

Heat is lost from the soil in a number of different ways; by radiation into the atmosphere, by conduction to the deeper, cooler layers of the soil or to the cooler air above, and by evaporation of water from the soil. King[7] states that the temperature of a cubic foot of saturated soil would be lowered 10.3° F. in evaporating one pound of water from it if all the heat needed for evaporating the water were drawn from the soil.

Mosier and Gustafson[8] have calculated that if all of the energy from a vertical sun in a clear sky were absorbed by the top 6 inches of soil the soil temperature would be raised 24.5° in an hour.

These authors report the average temperature found under bluegrass sod at varying depths and at different times of the year showing a more constant temperature at the deeper depths, the change in temperature at three feet in depth lagging behind the surface in both warming up and in cooling off.

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[7] King, Franklin Hiram.—*Textbook of the Physics of Agriculture*, 6th ed., p. 220. Mrs. F. H. King. Madison, Wis. 1914.

[8] Mosier, J. G., and Gustafson, A. F.—*Soil Physics and Management*, p. 307 J. P. Lippincott Co. Philadelphia, 1917.

173. Color of Soil and Temperature. Bouyoucos[9] studied the effect of color on the absorption of heat from the sun during hot, clear days. The average temperature of black sand was 40.9° C.; green, 37.10° C.; and white 34.6° C.

He found that in the spring gravel and sand thawed first, followed by clay 1 day later, loam 2 days later, and peat 10 days later.

174. Organic Matter, Decay, and Temperature. Georgeson[10] reports a case where 10, 20, 40, and 80 tons of manure were applied per acre to a sandy soil. In comparison with a soil where no manure was applied the increase in temperature was 0.60, 1.2, 2.1, and 3.2 degrees F., respectively.

Bouyoucos[11] also found that there was a rise in temperature with each increase in the quantity of manure used, but the degree of rise was believed to be insignificant for practical farm conditions.

Hall[12] states that growth will continue later in the autumn on the heavier soils than on the lighter soils. He points out that clay soil is slow to warm in the spring and that a high specific heat causes it to cool correspondingly slower after the heat of the summer.

Mosier and Gustafson,[13] reporting temperatures on drained and undrained land, show little difference in the morning but 7 to 8 degrees of difference in the evening, the drained soil having the higher temperature.

THE SOIL SOLUTION

175. The Soil Solution. The soil solution is the water of the soil with its dissolved substances. Plant nutrient materials and other substances of the soil are only partially soluble in water. The amount of a particular substance in the soil solution depends on several factors. The quantity and solubility of the material supplying the substance is of first importance. Particles of this material are given off into the solution, usually tending to maintain a definite concentration of that substance. These particles, going into solution, are ionized and are taken from the solution by passing into and becoming a part of the plant, by being absorbed from the solution by the soil particles, and by entering into combination with other ions of the solution.

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[9] Bouyoucos, Geo. J.—"An Investigation of Soil Temperature and Some of the Most Important Factors Influencing It." *Mich. Agr. Expt. Sta. Tech. Bul. 17*, p. 31. 1912.

[10] Georgeson, C. C.—"Influence of Manure on Soil Temperature." *Agricultural Science*, Vol. 1, p. 251. Nov., 1887.

[11] Bouyoucos, Geo. J.—"An Investigation of Soil Temperature and Some of the Most Important Factors Influencing It." *Mich. Agr. Expt. Sta. Tech. Bul. 17*, p. 193. 1912.

[12] Hall, A. D.—*The Soil*, 3rd ed., p. 130. John Murray, London. 1915.

[13] Mosier, J. G., and Gustafson, A. F.—*Soil Physics and Management*, p. 301, J. P. Lippincott Co. Philadelphia. 1917.

These processes result in reducing the concentration of the particular substance, after which more particles go into solution from the basic supply. In this way there are two forces working, one to maintain the concentration of the solution with reference to the particular substance, while the other force tends to reduce the amount in solution. One of the greatest factors influencing the concentration is the demands of the plant. In the case of nitrates the plant demands larger and larger amounts as it approaches maturity and the supply in solution may become practically depleted about harvest time. **(89)**

176. Selective Adsorption. Parker[14] reports as an important principle that soils have the power of adsorbing one ion at a greater rate than another,—selective adsorption. He states that when a soluble fertilizer salt is applied to a soil and exposed to rain, some of the salt may be leached out; but a greater or lesser amount will be adsorbed by the separate soil particles, either as a whole or selectively, and held by this same force till the plants or subsequent leaching removes it.

177. Horizontal Movement of Soluble Salts in Soil. Hopkins[15] cites the Rothamsted field where grass plots, separated only by a line, received different amounts of soluble fertilizer from nothing to 1 ton per acre annually for 52 years. The dividing lines between the plots has remained sharp and distinct; the rank herbage produced by the excess nitrogen fertilized plots has never extended 6 inches over the boundary line.

McCool and Wheeting[16] secured results rather contrary to those just reported and state that soluble salts move from regions of higher to regions of lower concentration in moist soils, the rate being rather rapid.

McCool and Millar[17] found that when large quantities of soluble salts were present there was a movement toward regions of lower concentration even when water movement was prevented and that the higher the water content of the soil the more rapid the movement.

Stewart and Martin[18] found that corn, horse beans, potatoes, turnips, and barley reduced the concentration of the water extracts during the height of the growing season, but that the concentrations are not significantly reduced unless the portion of the soil sampled is filled with plant roots.

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[14] Parker, E. G.—"Selective Adsorption by Soils." *Jour. Agr. Res.*, Vol. 1, No. 3, pp. 187-188. Dec. 10, 1913.

[15] Hopkins, Cyril G.—*Soil Fertility and Permanent Agriculture*, p. 366. Ginn and Co. New York. 1910.

[16] McCool, M. M., and Wheeting, L. C.—"Movement of Soluble Salts through Soils." *Jour. Agr. Res.*, Vol. 11, No. 11, p. 547. Dec. 10, 1917.

[17] McCool M. M., and Millar, C. E.—"Soluble Salt Content of Soils and Some Factors Affecting It." *Mich. Agr. Expt. Sta. Tech. Bul. 43*, pp. 46-47. 1918.

[18] Stewart, G. R., and Martin, J. C.—"Effect of Various Crops upon the Water Extract of a Typical Silty Clay Loam Soil." *Jour. Agr. Res.*, Vol. 20, No. 8, p. 667. Jan. 15, 1921.

178. Soil Toxin and Toxic Condition. (See also Rotations, Chapter 40.) The yield of a crop is sometimes reduced when the crop follows itself in continuous culture or when it is preceded by certain crops, such as sorghums, which have gained the reputation of being hard on the land. In some cases this reduction has been reported to be due to the accumulation of certain toxic organic substances in the soil solution.

Clements [19] states that the present facts appear to warrant the statement that organic toxins are excreted from the roots or produced in the soil only as a consequence of the anaërobic respiration of plant roots and of microöganisms and that inorganic toxins may arise as the result of chemical processes or adsorption. (See **111-114.**)

179. Sorghum, Flax, and Clover. One explanation of soil toxins is that they are the result of the decomposition of organic materials left in the soil as a result of plant growth. Sewell [20] reports that wheat grown after kafir produced 3 bushels per acre less over a period of 6 years than wheat grown after corn. In water cultures where wheat received its water supply from water percolating through perforated trays in which kafir and corn were grown, the kafir soil trays depressed the growth of wheat. He concluded that there were decomposition substances in the kafir trays which influenced the growth of wheat.

Breazeale [21] came to practically the same conclusion as Sewell with reference to toxic substances from sorghum. He stated that the toxic substances volatilize or completely decompose within a short time. It is suggested that while present this substance kills off the soil flora which generate carbon dioxide and a new equilibrium results in which sodium exists in excess of calcium, effecting a deflocculation of the soil.

Flax was supposed at one time to develop a toxic substance which prevented the further growing of this crop. Present knowledge would suggest that the unsatisfactory growth of the flax was due to the development of the flax wilt, a fungus disease. Under certain conditions when red clover has been grown continuously on the land for several years it has become difficult if not impossible to get satisfactory results with the crop. This "clover sick" condition of the soil has in some cases been credited to the accumulation of a toxin and in others to the presence of disease organisms.[22]

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[19] Clements, Frederic E.—"Aeration and Air Content," *Carnegie Inst. Wash. Pub. 315*, p. 162. 1915.

[20] Sewell, M. C.—"Effect of Andropogon Sorghum on Succeeding Crops of Triticum cativum vulgare." *Bot. Gaz. 75*, No. 1, p. 24. Mar., 1923.

[21] Breazeale, J. F.—"The Injurious After Effects of Sorghum." *Jour. Amer. Soc. Agron.*, Vol. 16, No. 11, p. 700. Nov., 1924.

Alkali in the Soil

180. Alkali Soils. Alkali soils are soils containing an accumulation of certain soluble salts which are harmful to plant growth. There are two well-known alkali conditions, usually referred to as "white alkali" and "black alkali." The white alkali is much more prevalent than the black and corrective measures are more successfully applied to it. Generally, white alkali consists of one or more of the non-alkaline salts of sodium such as the chlorides, sulphates, or nitrates. Black alkali consists of the alkaline salts of sodium such as the bicarbonate, baking soda, and the carbonate, sal-soda.

181. Formation of Alkali Soils. These different forms of alkali are derived primarily from the decomposing original rock. In sections where the rainfall is sufficient the alkali coming from this rock material is carried away by water, while in arid countries these salts may accumulate resulting in the alkali soils. Under irrigation, particularly without adequate drainage, the water table is likely to rise toward the surface and bring with it salts from the whole body of soil, these salts tending to concentrate near the surface as evaporation takes place. In the more humid sections alkali spots are often found around the borders of reclaimed sloughs. The water draining into these sloughs through the years carried with it more or less of these harmful salts which gradually accumulated as a result of evaporation.

182. Effect of Alkali on Plant Growth. An alkali soil condition may result in a poor, stunted, or abnormal growth with a drying, curling, or rolling of the leaves, much as would result from a lack of water. Yellowing, mottling, or other discoloration may indicate alkali injury. Much of the harm to plant growth is due to the effect of the salt in deranging the normal water relation existing between the plant and the soil. With a high concentration of salt the plant cannot obtain its normal amount of water; the water may even leave the plant when the concentration of the salts outside becomes too great. There may be some interference, also, with the normal adsorption of the necessary nutrients of the plant; due to an unbalanced condition certain nutrients may be recombined in an unavailable form as rapidly as they come into solution in the soil water.

Black alkali may change the composition of the soil solution so that plants cannot obtain enough iron, lime, or phosphorus for healthy growth. Black alkali is corrosive and has a decomposing action upon vegetative growth so that, when sufficiently concentrated, it will destroy plants with which it comes in contact. (154)

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[22] Fergus, E. N., and Valleau, W. D.—"A Study of Clover Failure in Kentucky." *Ky. Agr. Expt. Sta. Bul. 269*. 1926.

183. Relative Adaptation of Crop Plants to Alkali Soils. Harris and Pittman[23] state that the legume forage crops, especially such plants as vetches, cow peas, alfalfa, and sweet clover, are superior to the grass forages for alkali land. Cereal crops are among the best for alkali soils. Timothy and alsike are relatively non-resistant to alkali.

On the other hand Hibbard[24] states that, in general, the grasses, which include all of our cultivated grains, are more resistant to alkali than most other crops; that Bermuda grass and Rhodes grass are exceptionally tolerant of black alkali; that bluegrass and some other grasses, beans, peas, and melons are very sensitive to alkali; and that, with some marked exceptions, legumes are generally rather sensitive to alkali. These exceptions are old alfalfa, sweet clover, and hairy vetch.

Loughridge[25] states that the total amount of alkali in pounds per acre which various crops will stand without showing any harmful effect is as follows:

Saltbush	156,720
Alfalfa, old	110,320
Alfalfa, young	13,120
Sorghum	81,360
Vetch	69,360
Sunflower	59,840
Sugar beet	59,840
Barley	25,520
Wheat	17,280
Burr clover	17,000
Rye	12,480
Sweet clover	5,840

Breazeale[26] states that the limit of endurance of a plant for alkali salts seems to be determined by the amount of alkali required to kill the enzymes of the roots. He finds also that plants may be inoculated or immunized with calcium against alkali injury, similar to vaccination in animals.

184. Handling of Alkali Soils.[27] The most critical stage for most plants is the early leafing stage, and the time of planting may be

[23] Harris, F. S., and Pittman, D. W.—"Relative Resistance of Various Crops to Alkali." *Utah Agr. Expt. Sta. Bul. 168.* 1919.

[24] Hibbard, P. L.—"Alkali Soils—Origin, Examination, and Management." *Calif. Agr. Expt. Sta. Circ. 292.* 1925.

[25] Loughridge, R. H.—"Tolerance of Alkali by Various Cultures." *Calif. Agr. Expt. Sta. Bul. 133.* 1901.

[26] Breazeale, J. F.—"Alkali Tolerance of Plants Considered as a Phenomenon of Adaptation." *Ariz. Agr. Expt. Sta. Tech. Bul. 11.* 1926.

[27] McCrory, Samuel H., *et al.*—"A Bibliography Relating to Soil Alkalies." *U. S. Dept. Agr. Dept. Bul. 1314.* 1925.

selected so that the akali will either have been washed down into the soil or it may be turned under by plowing immediately before seeding the crop. In irrigated sections, quite commonly, a heavy irrigation is given before seeding, which carries the salts away from the young seedlings. Land can often be freed of white alkali by flooding and draining. The use of gypsum, sulphur, or other chemicals has sometimes given relief in cases of small amounts of black alkali by changing the form of the alkali to less harmful types.

Harris and Pittman[28] find that organic matter seems actually to remove sodium carbonates from the soil solution in large quantities. The liberal use of manure or other organic substances is recommended as beneficial to alkali soils, especially those high in carbonates.

White alkali has very little direct effect on the soil, but black alkali causes deflocculation, making it somewhat impervious to water. For this reason it has been found difficult to use flooding successfully as a remedy. When black alkali soils are dry they bake and form a hard crust. Deflocculation of the soil produces some shrinkage and results in a low spot in the field.

Breazeale and Burgess[29] find that gypsum is a corrective for black alkali in soils that contain no free carbon dioxide and will reduce the black alkali to about 25 parts per million in the soil solution but no lower. They suggest that after an application of gypsum, the soil should be leached in order to remove the soluble salts. They recommend leaching, the application of organic matter, and aeration by cultivation.

ACIDITY IN SOILS

185. Acid Soils. The term "acid soil" is used to designate a soil which shows an acid reaction when tested by well recognized chemical methods. If no acidity is shown, the soil is said to be "neutral" or "alkaline" as the case may be. Acid soils generally need lime to produce the most satisfactory yields though this is not necessarily the case as there are some very acid soils which do not respond to lime, while certain other soils which do respond to lime are not acid.

186. The Nature and Cause of Soil Acidity. There does not seem to be a common understanding of soil acidity or the causes bringing it about. An acid soil, often referred to as "sour," may be defined as a soil which contains an excess of acid substance over the bases present. Generally, soil acidity has been attributed to two distinct processes in the soil: first, the loss of lime and other bases from the soil by the direct use of crops or by leaching; and second, the production of acids by the decomposition of either organic or inorganic matter.

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[28] Harris, F. S., and Pittman, D. W.—"Soil Factors Affecting the Toxicity of Alkali." *Jour. Agr. Res.*, Vol. 15, No. 5, p. 319. Nov. 4, 1918.

[29] Breazeale, J. F., and Burgess, P. S.—"The Reaction between Calcium Sulphate and Sodium Carbonate and Its Relation to the Reclamation of Black Alkali Lands." *Ariz. Agr. Expt. Sta. Tech. Bul. No. 6.* 1926.

When organic matter decays in the soil various organic acids are produced which, uniting with bases of the soil, form neutral salts. If the acids are produced rapidly, the basic materials are used up allowing the acids to accumulate and thus making the soil acid or sour. Inorganic acid may also be produced in considerable quantities in some soils; when ammonium sulphate is added to the soil as a fertilizer, some sulphuric acid is produced, while the application of muriate of potash may result in the formation of hydrochloric acid.

Clements [30] states that the cause of soil acidity is still a subject of earnest debate. "In muck soils and in bogs it is certain that the lack of oxygen and the accumulation of carbon dioxide are the principal factors which work injury to plants, while the organic acids resulting from anaërobiosis probably play some part also. Even in muck soils it is probably true that acidity is a consequence of anaërobic respiration and an effect rather than a cause." (See **86**.)

In some soils acidity brings salts of aluminum, manganese, or iron into solution, and the plants absorbing them are injured. The main specific harmful influence of soil acidity is suggested by Truog [31] as being due in its effect in preventing certain plants from getting the calcium needed for neutralizing the organic acid produced in metabolism and growth.

187. Relative Adaptation of Crop Plants to Acid Soils. The ability of plants to grow on acid soil varies with the variety, the season and the soil, and may vary with the acids present in the soil. A number of investigators have studied the response of different crop plants to acid soils and to liming. The results reported vary widely.

Hartwell and Damon [32] have listed a large number of crops with reference to their ability to grow on acid soils as determined from pot cultures. Crops which thrived better without the addition of lime than with it were: peanuts, serradella, and watermelons.

Mooers [33] studied the response of different crops to the liming of acid soils where liming was necessary in order to get a fair crop of clover. Plants reported as practically failing without liming were:

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[30] Clements, Frederic E.—"Aeration and Air Content." *Carnegie Inst. Wash. Pub. No. 315*, p. 141. 1921.

[31] Truog, Emil—"Soil Acidity: I. Its Relation to the Growth of Plants." *Soil Sci.*, Vol. 5, p. 192. 1918.

[32] Hartwell, Burt L., and Damon, S. C.—"The Comparative Effect on Different Kinds of Plants of Liming an Acid Soil." *R. I. Agr. Expt. Sta. Bul. 160*. 1914.

[33] Mooers, Charles A.—"Liming for Tennessee Soils." *Tenn. Agr. Expt. Sta. Bul. 97*. 1913.

alfalfa, alsike clover, red clover, and white clover; crops which were decidedly helped: crimson clover, cowpeas, soybeans, velvet beans, and hairy vetch; crops which were injured by the application of lime were cotton, peanuts, and watermelons.

Truog[34] has grouped crops into high, medium, and low lime requirement crops, based on experiments carried out by himself and those of other workers. Certain crops were found able to tolerate acid conditions and make fair growth but also responded to liming.

High, medium, and low lime requirement groups:

HIGH	MEDIUM	LOW	
Alfalfa	Barley	Alsike	Soybeans
Cabbage	Corn	Buckwheat	Vetch
Canning peas	Potatoes	Cowpeas	Cotton
Onions	Red clover	Millet	Crimson clover
Sugar beets	Timothy	Oats	Japan clover
Sweet clover	Wheat	Red top	Sugar cane
Tobacco		Rye	Velvet beans

Jefferson,[35] working with Hughes at the Iowa station, summarized all the information which could be had from the different stations with reference to the adaptation of various legume crops to acid soils and also made comparisons in acid soils in pots in the greenhouse. He placed the legumes in three groups as follows: (I) Legumes which ordinarily will not do well on acid soils: the biennial sweet clovers, Hubam clover, annual yellow sweet clover, and alfalfa. (II) Legumes benefited by lime but which will make a fair growth on moderately acid soils: Canada field peas, medium red clover, mammoth red clover, crimson clover, white clover, alsike clover. (III) Legumes not seriously affected by soil acidity: burr clover, sulla, vetches, field beans, soybeans, Cherokee clover, kudzu, peanuts, velvet beans, cowpeas, Japan clover or lespedeza, blue lupine, and serradella.

Coville[36] mentions particularly potatoes, sweet potatoes, rye, oats, millet, buckwheat, redtop, corn, turnips, cowpeas, soybeans, hairy vetch, crimson clover, lupine, and serradella as acid tolerant crops. He suggests that under certain economic conditions a complete system of acid land agriculture is practicable and desirable. He points out that soil acidity may be beneficial in the control of certain fungus diseases of some of the cultivated plants, particularly scab of potato, the root rot of tobacco, chlorosis of pineapple, and perhaps other diseases.

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[34] Truog, Emil—"Testing Soils for Acidity." *Wis. Agr. Expt. Sta. Bul. 312.* 1920.

[35] Jefferson, Richard Ralph—*Legumes Adapted to Acid Soils.* Thesis. Iowa State College Library. 1924.

[36] Coville, Frederick V.—"The Agricultural Utilization of Acid Lands by Means of Acid Tolerant Crops." *U. S. Dept. Agr. Dept. Bul. 6.* 1913.

188. The Liming of Acid Soils. The generally recommended method for treating acid soils is to apply lime. Arthur Young mentioned the fact in the *Annals of Agriculture*, published from 1780 to 1800, that "chalking" the land is a good treatment for the soils, indicating that the use of calcium on the land was a recognized practice of that day. Lime is applied for the purpose of supplying calcium and of correcting certain soil conditions that have been found injurious to crops. Most workers regard the use of lime for the correction of soil acidity as the more important.

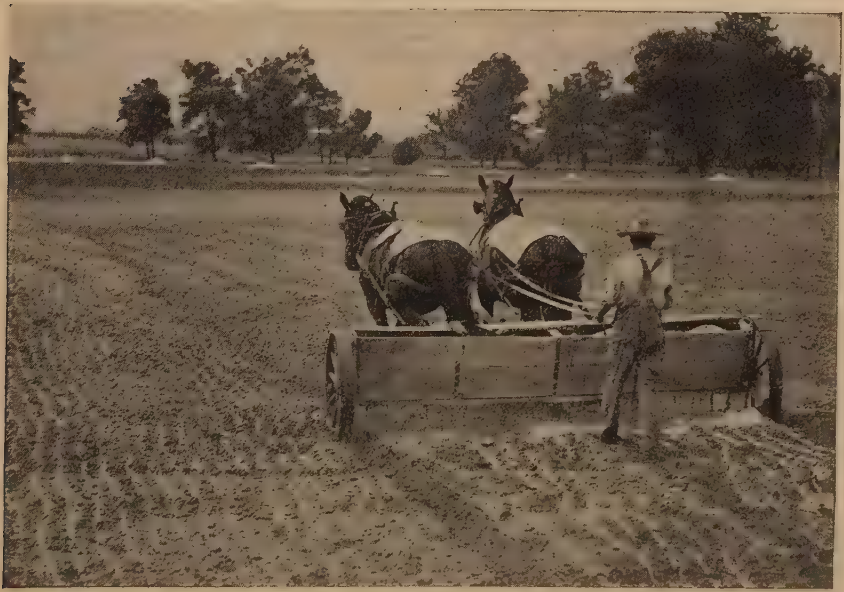

FIG. 52.—The application of finely ground limestone to acid soils has become an established practice preceding the growing of alfalfa and sweet clover. *Under what conditions is the liming of soil inadvisable? Under what conditions is it advisable?*

Quick lime, hydrated lime, and air-slacked lime have been used to a certain extent, but by far the greatest use has been made of finely ground limestone. The value of this rock depends upon the percentage of calcium or magnesium carbonate that the original rock contains and the fineness of grinding.

189. Fineness of Limestone. The limestone used on soils has varied greatly in the fineness of grinding. A number of workers report that limestone ground fine enough to pass a 20-mesh screen is sufficiently fine for agricultural purposes if none of the finer particles are removed before applying. In general, the coarser the material applied the longer it must be on the ground before it becomes actually effective.

White and Gardner[37] screened limestone into grades and tested its effect in correcting acidity. Limestone dust screened out with a 100-mesh screen (100-mesh per inch) and applied to a particular soil gave an alkaline reaction to the soil the first year, but by the end of the third year the soil again showed slight acidity; the 60-mesh stone did not give an alkaline soil until th esecond year; the 20-mesh stone at the end of the third year, while soil to which the 8-mesh limestone was applied still showed a lime requirement of 3000 pounds at the end of 3 years.

Hartwell and Damon[38] report a test in which fine and coarse limestone were compared on alfalfa. The finer the limestone the larger the yield the first crop year. Two years later the yields were about equal, while in the fourth and fifth years the plots which had received the finest limestone gave lower yields than those to which the coarser limestone had been added originally.

190. The Economics of Liming. Slipher[39] found the total liming cost per acre to be $11.25 where the price of limestone, freight included, was $3.50 per ton, the wagon haul 5 miles and the application was 2 tons per acre. He found that as an average for the country as a whole, liming cost $3.00 per acre each year. The states studied by Slipher were the northern and eastern section of the United States, including Missouri. He found that as a general average the net return by various crops from lime applied in the rotation was for cereals $1.71 per acre; legumes, $5.51; other forages, $2.70; pasture, $4.33; root crops, $13.76. Among the legumes clover gave a return of $5.30; alfalfa, $8.50; soybeans, $3.00; and cowpeas, $0.24. In applying lime some items of cost are likely to be overlooked.

191. Lime and Soil Structure. In addition to benefiting crops directly, lime, when applied in large amounts, modifies the structure of many soils. Such modification is marked in the case of clay loams. Liming makes the soils somewhat less cohesive and sticky when wet and more pliable and mellow when dry by gathering together the finer particles of clay into granules or crumbs, a process called flocculation. Useful nitrifying organisms thrive best in a soil containing lime.

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[37] White, J. W., and Gardner, F. L.—"The Value of Limestone of Different Degrees of Fineness." *Penn. Agr. Expt. Sta. Bul. 152.* 1918.

[38] Hartwell, B. L., and Damon, S. C.—"A Field Comparison of Hydrated Lime with Limestone of Different Degrees of Fineness." *R. I. Agr. Expt. Sta. Bul. 180,* pp. 5-12. 1919.

[39] Slipher, John A.—"The Economics of Soil Liming." *Jour. Amer. Soc. Agron.,* Vol. 17, No. 4, pp. 216-224. Apr., 1925.

SOIL ORGANISMS AND PLANT GROWTH

The greatest change taking place in most soils is in connection with the organic matter content. The organic matter influences the physical condition, the moisture holding capacity, the humus content, temperature, nitrogen content, and numerous bacterial processes which affect the availability of minerals in plant and animal bodies. Many of the beneficial effects of organic matter are connected with the work of soil organisms.

192. Soil Organisms. Nearly all soils contain a large number of organisms, both plant and animal, that act upon the organic and mineral constituents of the soil. Some of the larger organisms, such as rodents, insects, worms, and green plants, assist in opening up the soil for aëration by moving the soil to different levels and after death their decaying bodies supply plant food nutrients.

Darwin states that where earth worms abound the amount of soil brought to the surface by them each year forms a layer from 0.1 to 0.2 of an inch in thickness, or 15 to 30 tons per acre. Russell[40] found that earth worms did not seem to have any direct effect upon the production of plant food. The organic matter of the soil seemed to be decomposed and nitrates formed with equal rapidity whether earth worms were present or not. He thinks that their chief work is as cultivating agencies, loosening and mulching the soil, thus facilitating aëration and drainage.

The physical effect of the penetration by plant roots and the subsequent dying of these roots, leaving openings or passages down into the deeper layers of the soil, is important. Plants also add organic matter to the soil through the decay of the roots and top growth, and this has a marked effect on soil tilth, moisture retention, and available plant nutrients.

Fungi are important aids in the decomposition of cellulose; they also are necessary in producing ammonia from protein substances. Many species resemble the bacteria very closely. Bacteria have received a great amount of study and their work is better understood than that of the other small soil organisms.

193. Numbers and Distribution of Organisms. Waksman[41] made studies of bacteria in a garden plot, an orchard, a meadow, and a forest soil. He determined the average distribution throughout the year at equal depths below the surface. The results are given in Table *193a*.

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[40] Russell, Edward John—"The Effect of Earth Worms on Soil Productiveness." *Jour. Agr. Sci.*, Vol. 3, p. 257. Sept., 1910.

[41] Waksman, Selman A.—"Bacterial Numbers in Soils, at Different Depths, and in Different Seasons of the Year." *Soil Sci.*, Vol. 1, No. 4, pp. 363-380. Apr., 1916.

193a. Number of bacteria in different soils at different depths (inches) below the surface (000 omitted). Waksman.

SOIL TYPE	1 IN.	4 IN.	8 IN.	12 IN.	20 IN.	30 IN.
Garden soil ..	7,202	7,737	3,998	1,312	624	381
Orchard soil ..	8,257	5,577	2,863	1,527	547	347
Meadow soil ..	10,133	5,758	2,850	1,007	370	236
Forest soil ...	2,088	1,172	482	311	169	104

The garden soil had its highest number of bacteria in April, the orchard soil in June, the meadow soil in October, and the forest soil in August. A large number of workers have reported a decrease in bacteria in the deeper layers of soil.

194. Soil Organisms in the Decay of Organic Matter. Many species of soil organisms are specialized and attack only one principal substance, breaking it down, utilizing certain substances and leaving other secondary products. These secondary products may in turn be attacked by other species and carried still further toward complete decomposition. The complete decomposition of the complicated substances eventually results and the materials resolve themselves into simpler compounds of carbon, hydrogen, nitrogen, etc., such as CO_2, H_2O, and SO_2. The more resistant substances collect in the soil during this decomposition process forming humus, which is itself finally completely decomposed. In connection with these changes in organic matter there are several other important changes,—the processes of ammonification, nitrification, denitrification, and cellulose decomposition.

One of the products liberated in the decay of organic matter, particularly of proteins, is ammonia. This process, known as ammonification, is the result of the activities of a number of different species of bacteria and fungi. The nitrogen of the ammonia is transformed into nitrites by a limited number of species of bacteria, and the nitrite nitrogen is changed to nitrates by apparently a single organism, the nitrobacter. This change of the nitrogen in the ammonia form to the nitrate form is known as nitrification. Nitrogen is used by crop plants, generally in the form of nitrates, although some crops use it in the form of ammonia. The bacteria bringing about the above changes, resulting in nitrate formation, function best in well-aërated soils with moderate amounts of organic matter present.

There are a number of organisms which can break down the nitrites, using the oxygen, and when this is done the nitrogen is set free as a gas. Nitrates may be reduced to nitrites and then the nitrogen set free by this process. This is sometimes called denitrification and occurs in soils not well supplied with free oxygen, such as water logged soils, bogs, or very heavy compact moist soils.

In the process of breaking down organic matter the soil organisms consume nitrogen. This nitrogen is usually obtained from the material on which they are working, but if this material contains a very small per cent of nitrogen and is high in carbohydrate the organisms may use the available nitrates of the soil, in this way decreasing its productivity. For example, the application of a heavy layer of straw may result in a lowering of the available nitrates in the soil.

Other groups of soil organisms have the ability of breaking down cellulose. Some of these organisms are aërobic, and others anaërobic; some are bacteria, and others fungi. Their work is not well understood.

195. The Fixation of Atmospheric Nitrogen. There are two classes of bacteria which are able to add nitrogen to the soil supply by taking gaseous atmospheric nitrogen and transforming it into combined forms of nitrogen which can be used as plant food: those which live in the soil independent of the presence of growing plants and those bacteria which live in a symbiotic relationship with plants. To the first class belong the azotobacter and while not the only bacteria of this class they are probably the most efficient of the group. The work of nitrogen fixing bacteria is limited, due to the fact that they require a generous supply of carbohydrate material and the presence of calcium or magnesium carbonate. The azotobacter are aërobic and are affected injuriously by an acid condition. The lack of available phosphoric acid has been shown to be a limiting factor in nitrogen fixation by azotobacter.

Gainey [42] found that the azotobacter would not live in soils that were more acid than pH 6.0.

Lipman [43] is credited with the statement that different investigators have estimated the quantity of nitrogen fixed by azotobacter at 15 to 40 pounds per acre per annum.

Hall [44] analyzed a soil to a depth of 27 inches, from land which had been allowed to run wild for 20 years. An apparent gain of 95 pounds of nitrogen per acre had been made in one field and about half as much in another. The percentage of legume plants growing wild on the one soil was 25 while on the other it was less than half of 1 per cent.

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[42] Gainey, P. L.—"A Study of the Effect of Changing the Absolute Reaction of Soils Upon Their Azotobacter Content." *Jour. Agr. Res.*, Vol. 24, No. 24, p. 296. Apr. 28, 1923.

[43] Marshall, Charles E. (ed.)—*Microbiology*, 3rd ed., p. 405. P. Blakiston's Sons and Co. Philadelphia. 1921.

[44] Hall, A. B.—"On the Accumulation of Fertility by Land Allowed to Run Wild." *Jour. Agr. Sci.*, Vol. 1, pp. 241-249. 1905.

196. Symbiotic Bacteria. Hellriegel and Wilfarth demonstrated in 1886 and 1888 that legumes entered into a physiologic relationship with certain bacteria, in this way making it possible to use the atmospheric nitrogen. The bacteria which are responsible for and live and multiply in the tubercles on the roots of leguminous plants are rod-shaped, motile organisms (Rhizobia). The relation between the organism and the plant is truly symbiotic as the plant gets nitrogen by means of the organism while the organism gets a suitable media in which to grow.

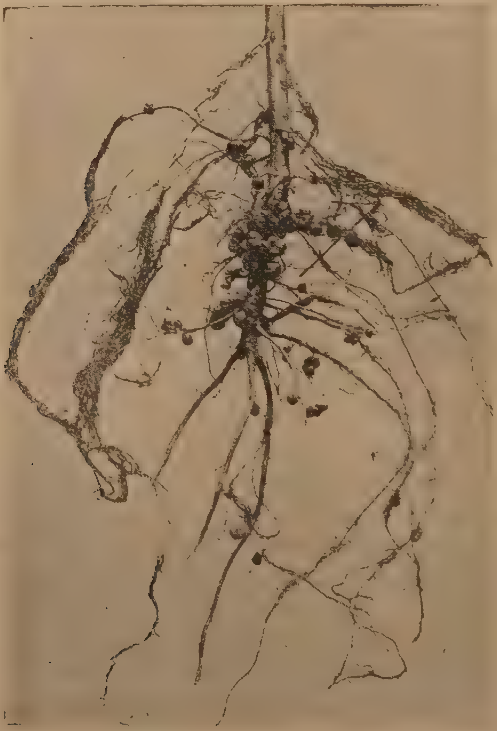

Fig. 53.—Nodules on the roots of a soybean plant. Few legumes can be grown successfully without the soil organisms which are responsible for the formation of these nodules.

197. Legume Bacteria Groups. There are several so-called strains of the legume bacteria and those from the nodules of one legume will not necessarily inoculate other legumes.

Many cross-inoculation experiments have been made; the work of Burrill and Hansen[45] at the Illinois Experiment Station and of

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[45] Burrill, Thomas J., and Hansen, Roy—"Is Symbiosis Possible between Legume Bacteria and Non-Legume Plants?" *Ill. Agr. Expt. Sta. Bul. 202.* 1917.

Garman and Didlake[46] at the Kentucky Station will be found of particular interest. A classification[47] which includes the more important legume crops and which indicates those which may be inoculated by the same strain of bacteria is given in Table *197a.*

197a. Legumes grouped on the basis of those which may be inoculated by the same strain of bacteria.

I. Alfalfa Group
  - Alfalfa
  - Burr clover
  - Sweet clovers
  - Yellow trefoil

II. Red Clover Group
  - Berseem
  - Alsike clover
  - Crimson clover
  - Red clover
  - Mammoth red clover
  - White clover
  - Zigzag clover

III. Cowpea Group
  - Cowpea
  - Lima bean
  - Mung bean
  - Tepary bean
  - Velvet bean
  - Florida beggarweed
  - Lespedeza

IV. Vetch Group
  - Horse bean
  - Lentil
  - Canada field pea
  - Garden pea
  - Perennial sweet pea
  - Sweet pea
  - Tangier pea
  - Vetches

V. Soybean Group
  - Soybean

VI. Bean Group
  - Garden bean
  - Pinto bean
  - Scarlet runner bean

VII. Lupine Group
  - Lupines
  - Serradella

198. Inoculation. The presence of the proper bacteria is necessary if the crop is to use the nitrogen from the air. On soils rich in nitrates some legumes, such as the soybean, are able to make a vigorous and apparently normal growth without the aid of nodule bacteria. When such a legume as the soybean is grown without the nodule bacteria it must of necessity take all of the nitrogen from the soil and under these conditions may deplete the nitrogen content of the soil more rapidly than any of the non-legume crops which might be grown.

The red clover nodule bacteria are now generally distributed throughout most of the corn belt, as well as in some other parts of the United States. The alfalfa and sweet clover bacteria are not naturally present in many soils and this is even more true for soybeans. When these bacteria are not naturally present in soils it is necessary to artificially introduce them if legumes are to be grown satisfactorily in the rotation.

199. Methods of Inoculating. The early methods of inoculation were rather cumbersome. The soil transfer method is one of these early methods and consists in spreading 300 to 500 pounds of soil per acre on the new field, obtained from a field where a legume of the same group, known to be inoculated as indicated by the nodules on the roots, has been grown. The method is not generally advocated at present due to the labor involved, though it is possibly the most effective practice which can be suggested. Erdman and Wilkins,[48] studying methods of inoculating soybeans at the Iowa Station in 1924, report the degree of inoculation secured by different methods shown in Table *199a*.

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[46] Garman, H., and Didlake, Mary—"Six Different Species of Nodule Bacteria." *Ky. Agr. Expt. Sta. Bul. 184.* 1914.

[47] Pieters, A. J.—*Green Manuring,* pp. 140-141. John Wiley and Co. New York 1927.

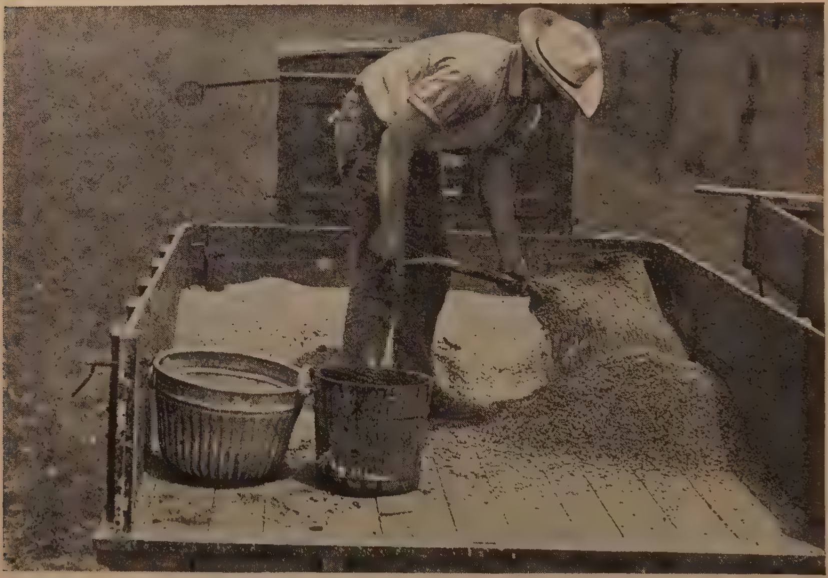

Fig. 54.—Inoculating soybean seed. Inoculation is essential for the most successful growing of this crop on most soils where it has not previously been produced.

The extreme care formerly advocated in handling inoculated soil and seed does not seem to be necessary as sunlight and frost have not proven as deadly to the bacteria[49] as they were thought to be.[50] Soybean seed to which culture had been applied and then exposed to direct sunshine gave practically as good inoculation at the Iowa Station as beans protected from sunlight.[51] It seems desirable, how-

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[48] Erdman, Lewis W., and Wilkins, F. Scott—"Soybean Inoculation Studies." *Iowa Agr. Expt. Sta. Res. Bul. 114*, p. 19. 1928.

[49] Fred, E. B., and Davenport, Audrey—"Bacteria for Legumes." *Wis. Agr. Col. Ext. Circ. 143*. 1922.

[50] Albrecht, Wm. A.—"Viable Legume Bacteria in Sun Dried Soil." *Jour. Amer. Soc. Agr.*, Vol. 14, No. 1, pp. 49-51. Jan.-Feb., 1922.

[51] Erdman, Lewis W., and Wilkins, F. Scott—"Soybean Inoculation Studies." *Iowa Agr. Expt. Sta. Res. Bul. 114*, p. 35. 1928.

199a. Different methods of inoculating soybean seed compared. Iowa.

METHOD	PER CENT OF PLANTS WITH NODULES				
	None	Poor	Medium	Good	Total Inoculation
No inoculation	97.5	2.5	0.0	0.0	2.5
Soil—Sugar solution method ...	8.75	46.25	42.5	2.5	91.25
Soil—500 lbs. per acre	0.0	21.25	56.25	22.5	100.00
Commercial culture No. 1......	56.25	38.75	5.0	0.0	43.75
Commercial culture No. 2......	0.0	37.5	56.25	6.25	100.00
Commercial culture No. 3......	1.25	23.75	66.25	8.75	98.75
Commercial culture No. 4......	50.00	40.00	10.00	0.0	50.0

ever, to plant immediately after inoculating the seed if the best inoculation is to be secured.

200. Amounts of Atmospheric Nitrogen Used by Legumes. The amount of atmospheric nitrogen used by inoculated plants varies widely. When grown on soils very low in nitrates a larger proportion of the nitrogen used by the plant will be obtained from the atmosphere than when grown on soils rich in this nutrient. Pieters in his book on green manure crops has summarized the literature on this subject. Hopkins [52] estimated that inoculated alfalfa and sweet clover under ideal conditions may obtain as much as two-thirds of their nitrogen from the air, while Alway and Pinckney [53] calculated that inoculated alfalfa obtained 40 to 52 per cent of its nitrogen from the air.

Lipman and Blair [54] calculated that 150 of the 200 pounds of the nitrogen contained in the product of an acre of alfalfa came from the air; Arny and Thatcher [55] that alfalfa bacteria had fixed 10 to 48 pounds per acre. Fred and Graul [56] found that inoculated alfalfa fixed 59 pounds per acre in the tops in one case, 81 pounds in another and 269 pounds in still another. Smith and Robison [57] calculated that inoculated soybeans took 26 per cent of their nitrogen from the air,

[52] Hopkins, Cyril G.—*Soil Fertility and Permanent Agriculture*, p. 217. Ginn and Co. Boston. 1910.

[53] Alway, Fred J., and Pinckney, R. M.—"The Nitrogen Content of Inoculated and Uninoculated Alfalfa Plants." *Nebr. Agr. Expt. Sta. Ann. Rpt. 23*, pp. 33-34. 1910.

[54] Lipman, Jacob G., and Blair, A. W.—"Cylinder Experiments Relative to the Utilization and Accumulation of Nitrogen." *N. J. Agr. Expt. Sta. Bul. 289.* 1916.

[55] Arny, A. C., and Thatcher, R. W.—"The Effect of Different Methods of Inoculation on the Yield and Protein Content of Alfalfa and Sweet Clover." *Jour. Amer. Soc. Agron.*, Vol. 7, pp. 172-185. 1915; Vol. 9, pp. 127-137. 1917.

[56] Fred, E. B., and Graul, E. J.—"The Gain in Nitrogen from Growth of Legumes on Acid Soils." *Wis. Agr. Expt. Sta. Res. Bul. 39.* 1916.

[57] Smith, C. D., and Robison, F. W.—"Influence of Nodules on the Roots upon the Composition of Soybeans and Cowpeas." *Mich. Agr. Expt. Sta. Bul. 224*, pp. 128-137. 1905.

while Fred[58] reports that this plant took 87 per cent from the air.

Nobbe and Richter[59] found that with no soil nitrates present inoculated hairy vetch took 93.8 per cent of its nitrogen from the air while with an abundant supply the percentage was 79 per cent and 73 per cent.

Hopkins' statement that properly inoculated leguminous plants take two-thirds of their nitrogen from the air is rather widely used as a general statement of this relation.

Other data on nitrogen additions are found under green manures. (218-225)

201. Bacterial Symbiosis in Non-legumes. Wilson[60] has viewed the literature on bacterial symbiosis in non-legumes. He finds that Zimmerman first found bacteria in nodules on the leaves of certain tropical plants (*Rubiaceen*). Miehe found bacteria spreading through a tropical plant (*Ardisia crispa*) and demonstrated that these bacteria could fix nitrogen. Boas listed six species of *Rubiaceen* and one of *Myrsinaceen* which have leaf nodules and Von Faber demonstrated the ability of these bacteria to produce the nodules and to fix nitrogen.

202. Nitrogen Added by Rainfall. Freeman[61] reports that with an average rainfall for six different locations in Kentucky of 42.76 inches for the year April 1, 1922, to April 1, 1923, the soil received an average of 18.78 pounds of nitrogen per acre. Of this amount, 11.61 pounds was in the form of ammoniacal nitrogen and 7.17 pounds was in the form of nitrate nitrogen.

King[62] reports work at widely separated places in Europe showing variations of from 1.86 to 20.91 pounds (average 10.23 pounds) of nitrogen per acre added by rainfall with a rainfall average of 27.03 inches.

STUDY QUESTIONS ON CHAPTER VII

1. Much farm land has been abandoned in the southeastern part of the United States. Why?
2. There is more carbon dioxide in the air of a clay soil than in a sandy soil. Why? There is more in the air of a soil with a crop on the land than without. Why?

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[58] Fred, E. B.—"The Fixation of Atmospheric Nitrogen by Inoculated Soybeans." *Soil Sci.*, Vol. 11, pp. 469-472. 1921.

[59] Nobbe, F., and Richter, L.—"Über den Einfluss des im Kulturboden vorhandenen assimilierbaren Stickstoffs auf die Aktion der Knöllchenbakterien." *Landw. Vers. Sta.*, Vol. 59, pp. 167-174. 1903.

[60] Wilson, J. K.—"Bacterial Symbiosis in Plants Other than Legumes." *Jour. Amer. Soc. Agr.*, Vol. 16, No. 6, p. 373. June, 1924.

[61] Freeman, J. F.—"Nitrogen in the Rainfall at Different Points in Kentucky." *Jour. Amer. Soc. Agr.*, Vol. 16, No. 5, p. 358. May, 1924.

[62] King, Franklin Hiram.—*The Soil*, p. 120. Macmillan Company. New York. 1906.

3. Would it stimulate plant growth to increase the amount of carbon dioxide in the soil. Why?
4. Why does corn grown on land in need of drainage turn yellow? What can be done to improve the growing conditions? Explain.
5. In what order are the standard crops of your section planted in the spring. Why?
6. What makes a soil an early or a late soil for planting? List the factors affecting the temperature of a soil. Explain the influence of each.
7. What is the soil solution? With a heavy crop of wheat on the land, picture the changes in the soil solution. How does this differ when the soil is fallow?
8. How do certain non-nutritive salts make nutritive salts available?
9. In applying fertilizers how close to the hill or row should they be placed? Why?
10. How can a soluble salt interfere with plant growth? Why are our great alkali areas in regions of low rainfall?
11. In what ways can alkali soils be made productive?
12. What are the factors which may result in a soil showing an acid condition?
13. Classify the common crops of your section as to their ability to grow on acid soils. On alkali soils.
14. Under what conditions and in what way is an application of lime to soil likely to be beneficial?
15. Outline the changes which take place during the breaking down process in the decay of organic matter.
16. What do we mean by the inoculation of legumes? Under what conditions is this advisable and how may it best be brought about?

APPLICATION ASSIGNMENTS ON CHAPTER VII

1. A field which was planted last year, one-half to sorghum and one-half to potatoes, is planted this year to corn. The corn crop following the sorghum is making 20 bushels per acre less than that following the potato crop. Explain.
2. Two fields, a sandy loam and a clay loam, were fall-plowed for corn. Which will you plant first? Why?
3. On your farm corn is your cash crop. Two fields are available for this crop. One field was in wheat the previous year while the other was fallow. Both are rather low in fertility. On which field will you plant corn? Why?
4. A twenty-acre field, recently tiled, produces only a stunted, yellowed, and dwarfed growth of most crops. The surrounding fields are productive. What is the probable trouble? What crop will you grow? How can this condition be remedied?
5. A certain field produces good crops of corn and of oats but alfalfa and sweet clover fail. You wish to seed for a crop of hay. What will you grow? Why? How can this condition be remedied?

6. You are planting soybeans for the first time on soil which has grown well inoculated red clover and sweet clover three years previously. Will you inoculate the soybeans? Why?
7. You have grown inoculated soybeans on a field adjoining a field to be seeded this season. Will you inoculate the crop for this field? If so, why and how?

CHAPTER VIII

CROPPING PRACTICES AND SOIL PRODUCTIVITY

There are a number of conditions which may develop in the soil rendering it unfavorable for plant growth. Among the more important unfavorable factors or conditions are an excess of soil acids and a deficient supply of organic matter and of plant nutrients. In overcoming these conditions a number of overlapping processes and practices have come into use. The liming of acid soils has already been discussed.

It is a well established fact that the continuous growing and removal of crops from land soon results in decreased yields, unless special effort is made to restore soil losses. Reference has been made to the elements required for normal growth and the way in which these come into solution and become available to plants; determinations of the composition of the various crop plants show that all of these elements are present in larger or smaller amounts.

PLANT NUTRIENTS IN THE SOIL

203. Pounds Plant Nutrients per Acre. The amount of plant nutrients in the soil varies widely with the different types of soil, their location, and the use or treatment to which they have been subjected.

Hopkins[1] gives a rough approximation of the amount of some of the essential plant nutrients in an acre of average land to a depth of 6⅔ inches. The average silt loam soil to this depth is estimated at about 2,000,000 pounds. Of this 2,000,000 pounds, 2,200 would be phosphorus; 49,200, potassium; 48,000, magnesium; 68,800, calcium; 86,600, iron; and 2200 sulfur.

204. Nutrients Limiting Crop Yields. Hopkins[2] has stated that for all normal soils in the United States, and especially for those in the central states, there are only three constituents which must be supplied in order to adopt a system of farming which, if continued, will increase or at least permanently maintain the productive power of the soil. These are limestone (calcium), phosphorus, and organic matter (nitrogen). Other fertilizing materials have some value and perhaps great value on uncommon or abnormal soils, and may sometimes be used to advantage. Residual sands and peaty swamp land are usually deficient in potassium.

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[1] Hopkins, Cyril G.—*Soil Fertility and Permanent Agriculture*, p. 59. Ginn and Co. New York. 1910.

[2] *Ibid.*, p. 159.

Plant Nutrients Removed by Crops

205. Nutrients Removed Annually. It is perfectly obvious that when we grow crops year after year and remove these from the soil, that plant nutrients may be removed in this way to such an extent as materially to influence the productivity of a soil. The amounts of plant nutrients contained in a given unit of different crops is important, not only because of the nutrients removed from the soil but also because of the possible value of the waste products of these crops and of the manure produced from them in maintaining soil productivity. The amounts of the four plant nutrients which are most likely to limit yields are shown for some of the more important crops in Table *205a*.

Fig. 55.—Burning cornstalks in the spring preparatory to seeding oats. This is a common practice on many farms. *Under what conditions, if any, is it advisable to burn cornstalks in this way? When cornstalks are incorporated with the soil what is their value?*

205a. Plant food elements removed annually by field crops.[3]

CROP	YIELD PER ACRE	POUNDS EACH ELEMENT USED PER ACRE			
		Nitrogen	Phosphorus	Potassium	Calcium
Corn (grain)	50 bu.	50	8.5	9.5	1.0
Corn (stover)	1.5 T.	24	3.0	26.0	10.0
Corn (total)		74	11.5	35.5	11.0
Wheat (grain)	25 bu.	35.5	6.0	6.5	1.0
Wheat (straw)	1 T.	10.0	2.0	10.5	4.0
Wheat (total)		45.5	8.0	17.0	5.0
Oats (grain)	45 bu.	25.0	6.5	7.0	1.5
Oats (straw)	1.25 T.	12.0	3.0	27.0	6.0
Oats (total)		37.0	9.5	34.0	7.5
Barley crop	30 bu.	42.0	7.0	31.5	6.0
Alfalfa	3 T.	140.0	14.0	50.0	67.0
Clover hay	1.5 T.	60.0	7.5	45.0	33.7
Timothy hay	1.5 T.	36.0	4.5	33.7	8.0
Potatoes	100 bu.	22.0	4.5	30.0	2.0
Cotton (lint)	500 lbs.	1.5	2.4	0.5	...
Cotton (seed)	1000 lbs.	31.5	11.5	12.6	...

LOSSES RESULTING FROM CROPPING PRACTICES

206. Effect of Cultivation. Continuous cropping through a fifty-year period in many cases has resulted in very productive soil becoming unproductive. However, other losses of available plant nutrients from the surface soil may be even more important than by cultivated crops. The plowing, cultivating, and stirring,—aëration of soils,—which is necessary in our ordinary cropping practices, encourages erosion and stimulates oxidation and other breaking-down processes, making larger amounts of the different elements available in solution than would otherwise be the case. These available materials may be carried away and lost by percolation and leaching.

207. Soil Erosion. The National Conservation Commission[4] has estimated that of approximately 10,000,000 acres of abandoned land in the United States, almost 40 per cent of the abandonment has been the direct result of soil erosion.

The amount of the rain water which runs off[5] the soil surface depends upon the crop, the slope of the soil, the condition of its surface, and the character of the soil. The average runoff, due to average precipitation, is reported by the Texas station to be approximately as shown in Table *207a*.

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[3] Compiled from various sources; particularly from Brown, Percy Edgar.—"The Fertility in Iowa Soils." *Iowa Agr. Expt. Sta. Bul. 150.* 1914.

[4] "Natl. Cons. Comm. Rpt.," Vol. 1, U. S. 60th Cong., 2nd Session *Senate Doc. 646.* 1909.

[5] Fraps, G. S.—"Losses of Moisture and Plant Food by Percolation." *Tex. Agr. Expt. Sta. Bul. 171.* 1914.

207a. Runoff with different amounts of rainfall and slope. Texas.

Inches Rainfall	Inches of Run Off	
	Steep Slopes	Gentle Slopes
5	0	0
10	2	0
15	4	1
20	8	3
25	12	4
30	17	8
35	22	12
40	28	15
45	..	20

Dickson reporting from the Texas Station[6] in 1929 gives the data from recent studies showing, as a three-year average, the annual runoff and erosion.

Crop	Slope	Inches Runoff Water	Tons of Soil Eroded
Cotton	0 per cent	0.62	5.28
Cotton	1 per cent	3.42	9.3
Cotton	2 per cent	3.80	12.6
Cotton	3 per cent	3.15	12.78
Milo	2 per cent	2.22	5.74
Buffalo grass	2 per cent	1.52	3.80
Fallow cultivated	2 per cent	6.28	18.62
Fallow not cultivated.	2 per cent	7.72	21.76

Sampson and Weyl[7] found that the amount of soil removed by erosion was correlated very definitely with the nature of the rainfall, the slope of the land, the cover, and the rapidity of the flow of the runoff water.

208. Erosion Studies in Missouri. The Missouri Agricultural Experiment Station[8] began measuring erosion losses in 1917. The soil was a rather poor phase of Shelby loam having a dark gray surface soil about 8 inches deep with a moderately heavy subsoil lying on glacial material. The slope of the surface was 3.68 feet per hundred. The surface 7 inches of the soil was found to contain 0.112 per cent of nitrogen, 0.05 per cent of phosphorus, 1.24 per cent of potassium; a soil which would produce a little under 30 bushels of corn per acre in an average season.

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[6] Dickson, R. E.—"The Results and Significance of the Spur (Texas) Runoff and Erosion Experiments." *Jour. Amer. Soc. Agron.* Vol. 21, No. 4, p. 415. 1929.

[7] Sampson, Arthur W., and Weyl, Leon H.—"Range Preservation and Its Relation to Erosion Control on Western Grazing Land." *U. S. Dept. Agr. Dept. Bul. 675.* 1918.

[8] Duley, F. L., and Miller, M. F.—"Erosion and Surface Runoff under Different Soil Conditions." *Mo. Agr. Expt. Sta. Res. Bul. 63.* 1923.

The runoff and rate of erosion for the six-year period 1917-23 is shown in Table *208a*.

208a. Per cent of rainfall lost by runoff and tons of soil eroded per acre. Missouri.

Cropping	Per Cent of Rainfall Lost by Runoff	Tons of Soil Eroded in 6 Years	Years Required to Erode 7 Inches
1. Not cultivated (weeds scraped)	48.92	207.8	29
2. Plowed 4″ deep, cultivated	31.26	247.3	24
3. Plowed 8″ deep, cultivated	28.36	214.2	28
4. Sod	11.55	1.7	3,547
5. Wheat, annually	25.19	39.9	150
6. Rotation-corn, wheat, and clover	14.14	13.7	437
7. Corn annually	27.38	106.5	56

Over 50 per cent of the erosion was brought about by 16 heavy rains out of a total of 256 rains for the period.

The amount of plant nutrient lost in the Missouri studies was as shown in Table *208b*.

208b. Plant nutrients lost per acre in eroded material with different cropping methods. Two-year average. Missouri.

Cropping	Pounds Nitrate Lost Annually	Pounds Phosphorus Lost Annually	Pounds Calcium Lost Annually
1. Not cultivated (weeds scraped)	98.88	47.47	379.38
2. Plowed 4″ deep, cultivated	95.40	45.47	337.89
3. Plowed 8″ deep, cultivated	73.87	33.26	225.63
4. Sod	0.55	0.09	0.64
5. Wheat, annually	29.58	10.83	75.99
6. Rotation—corn, wheat, and clover	5.94	2.22	41.47
7. Corn, annually	40.36	8.14	103.37

The maximum lost by erosion was at two periods of the year, in the months of March and April and again in August and September.

209. Erosion Studies in North Carolina. Bartell,[9] working at the North Carolina Experiment Station, estimated the amount of runoff and soil eroded from plots of very fine sandy loam soil with a slope averaging about 9 per cent. Grass, corn, and cotton were grown on some of the plots and in other plots the soil was cultivated but not planted. It was reported that the runoff is apparently proportional to the intensity and the amount of rainfall rather than to the amount of rainfall alone. The average runoff was 35 per cent of the rainfall and the maximum for a single rain was 64 per cent. Fifty per cent of the erosion occurred during June when cultivation was carried on and before the crops had made material growth, while only 15 per cent of the total rainfall and 25 per cent of the runoff occurred during this time. Grass sod was efficient in decreasing both the runoff and erosion.

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[9] Bartell, F. O.—"First Progress Report on Soil Erosion Experiments." North Carolina Experiment Station Farm, West Raleigh, Wake County, North Carolina. *U. S. Dept. Agr. Bur. Pub. Roads, Div. Agr. Eng.* 1925.

210. Sheet Erosion and Gullying. There are two general types of erosion,—sheet erosion and gullying. *Sheet erosion* is where the entire plowed surface washes down to the bottom of the furrow slice and is carried away. *Gullying* is the washing out of ditches across the field. In many cases it starts with the furrows or rows of a cultivated crop where the land is rolling.

Various means of overcoming these two kinds of erosion have been suggested and are in use in certain sections of the country. A common practice in the South on rolling land subject to erosion is to terrace the land. The adoption of tillage methods which tend to absorb a greater portion of the rainfall is an important means of checking erosion.

211. Wind Erosion of Soils. Wind erosion of soils is a detrimental factor only in sections having large areas of flat, unprotected land such as are found in the semi-arid sections of the West. In humid sections, wind erosion is seldom a serious problem.

Udden[10] estimated that during an ordinary breeze a cubic mile of air may contain 255 tons of dust and that in a heavy storm this load of dust may be increased to 126,000 tons.

Walster[11] states that on soils at all inclined to drift, fall plowing is a very doubtful practice. Wind erosion is detrimental in the southwestern and central western parts of the Great Plains, where there is much sandy soil and strong winds are frequent. The wind, usually from the southwest, picks up particles of sand from especially loose portions of the field and with these as tools erodes the surface ahead, the erosion increasing rapidly until great clouds of dust and sand are formed. Soil blowing, long continued, will actually excavate the soil sometimes as deep as it is plowed. The effect on young plants is to cut them off as though with a knife and to bury the portion remaining.

Where soil blowing is destructive the general recommendation is that immediately the blowing begins, the entire field or strips should be disked or harrowed to roughen the surface and catch the soil. A lister is sometimes used, listing strips of land at right angles to the direction of the wind. Measures such as turning under of barnyard manure and green manure and the planting of shelter belts are also recommended as preventive measures.

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[10] Udden, J. A.—"Dust and Sand Storms in the West." *Pop. Sci. Mo.* Vol. 49, p. 655. 1896.

[11] Walster, H. L.—"Fall Plowing versus Spring Plowing for North Dakota Grain Crops." *N. Dak. Agr. Expt. Sta. Bul 141.* 1920.

Percolation and Leaching from Soils

Percolation is the passage of water down through the soil. In this process dissolved plant foods are taken up and carried away.

212. Loss of Nitrates by Leaching. The amount of nitrates lost in the drainage from crop soils has been shown to depend upon the kind of plants grown, ten times [12] as much being lost from some crops as from others, more being leached from soil growing alfalfa than from that growing timothy.[13]

Russell and Richards [14] at Rothamstead found nitrate losses in 1870 to be 40 pounds of nitrogen per acre annually where the soil had 3500 pounds of nitrogen per acre in the top 9 inches. At the end of 50 years, the soil contained 2328 pounds of nitrogen in the top 9 inches and had lost 23 pounds annually per acre. Analysis of the soil showed that practically all the nitrogen lost from the top 9 inches could be accounted for in the nitric nitrogen of the drainage.

Lyon and Bizzell [15] found that a clay loam containing 0.134 per cent of nitrogen lost only about 4.0 pounds of nitrogen per acre annually with a crop growing, but when not cropped the nitrogen losses averaged nearly 100 pounds. The importance of a growing crop as a means of preventing nitrogen loss is apparent.

Conner [16] states that average Indiana soils have lost approximately 20 pounds of nitrogen per acre per year for the last half century and some have lost 40 pounds.

213. Removal of Phosphorus by Leaching. In experiments including a wide range of climatic and soil conditions, in which drainage water has been analyzed, very little phosphorus has ever been found. The loss of phosphorus by leaching does not seem to be of serious concern.

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[12] Deherain, P. P.—"Sur la composition des eaux de drainage des terres nues et cultivées." *Ann. Agron.* Vol. 17, pp. 49-82. 1891.

[13] Thatcher, R. W.—"Lysimeter Investigations." *N. Y. Agr. Expt. Sta. Ann. Rpt. 40*, p. 17. 1921.

[14] Russell, E. J., and Richards, E. H.—"The Washing Out of Nitrates by Drainage Water from Uncropped and Unmanured Land." *Jour. Agr. Sci.* Vol. 10, pp. 22-43. 1920.

[15] Lyon, T. Littleton, and Bizzell, James A.—"Lysimeter Experiments." *N. Y. [Cornell] Agr. Expt. Sta. Mem. 12*, p. 36. 1918.

[16] Conner, S. D.—"Nitrogen in Relation to Crop Production in the Middle West." *Jour. Amer. Soc. Agron.* Vol. 14, No. 5, p. 181. May, 1922.

214. Removal of Potash by Leaching. Only small quantities of potash appeared in the percolate from most of the soils which have been studied in various parts of the country. The loss of potash in this way does not seem to be excessive.

215. Loss of Calcium by Leaching. Practically all drainage water analyses show that calcium is the chief constituent lost from the soil in large quantities. Lyon and Bizzell[17] found that the loss of calcium per acre during a five-year period averaged annually 194.2 pounds for a cropped soil, and for an uncropped soil 367.4 pounds.

Hall and Miller[18] report that the average annual loss per acre of calcium carbonate was, from plots (a) unmanured, 800 pounds; (b) receiving ammonium sulfate, 1100 pounds; (c) receiving sodium nitrate, 564 pounds.

Stewart and Wyatt[19] found the average annual loss of calcium carbonate per acre from the surface 20 inches under corn was 760 pounds; under oats, 542 pounds. The loss depended upon a number of factors among which were the kind, the form, and amount of limestone added.

Fraps[20] found that the loss of lime from uncropped, uncultivated soils varied from 70 to 582 pounds per acre.

216. Loss of All Nutrients, England. Data available from the Rothamsted station, cited by Hopkins,[21] showing the loss in plant nutrients in drainage waters as an average for a four-year period, 1866-69 inclusive, is of particular interest. (See *216a*, on page 177.)

217. Percolation Summary. Bizzell[22] has summed up the losses of plant food by percolation somewhat as follows: Large quantities of calcium are lost from the soil by drainage waters, generally amounting to more than all other nutrients together. Application of ammonium salts, especially ammonium sulfate, increases the loss of calcium. The quantities of magnesium and potassium removed are appreciable but not excessive. Nitrogen appears in drainage water almost entirely as nitrate. The general effect of cropping is to reduce the amount lost. The loss of nitrates from soils growing legumes ap-

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[17] Lyon, T. Littleton, and Bizzell, James A.—"Lysimeter Experiments." *N. Y.* [*Cornell*] *Agr. Expt. Sta. Mem. 12*, p. 49. 1918.

[18] Hall, A. D., and Miller, N. H. J.—"The Effect of Plant Growth and of Manures upon the Retention of Bases by the Soil." *Roy. Soc.* [*London*] *Proc.*, Ser. B, Vol. 77, pp. 1-31. 1905.

[19] Stewart, Robt., and Wyatt, F. A.—"Limestone Action on Acid Soils." *Ill. Agr. Expt. Sta. Bul. 212*, p. 296. 1919.

[20] Fraps, G. S.—"Losses of Moisture and Plant Food by Percolation." *Tex. Agr. Expt. Sta. Bul. 171.* 1914.

[21] Hopkins, C. G.—*Soil Fertility and Permanent Agriculture*, p. 413. Ginn and Co. New York. 1910.

[22] Bizzell, J. A.—"Removal of Plant Nutrients in Drainage Waters." *Jour. Amer. Soc. Agron.* Vol. 18. No. 2, p. 135. Feb., 1926.

216a. Composition of drainage waters from Broadbalk field.

(Averages for the four years, 1866, 1867, 1868, 1869. Pounds in 3,000,000 of water corresponding to pounds per acre for 13⅓ inches of drainage.)

	Farm Manure (15.7 tons)	Unfertilized	Ammonium Salts and Minerals
Nitrogen per acre (lbs. applied)	......	None	43
Total salts per acre (" ")	......	None	992
Wheat, av. yield, bu.	37.5	14.5	25.7
Ammonia nitrogen (in drainage)	.5	.4	.6
Nitrate, as nitrogen "	48.3	11.7	25.5
Total nitrogen (N) "	48.8	12.1	26.1
Phosphorus (P) "	......	.8	2.0
Potassium (K) "	13.5	4.2	11.0
Magnesium (Mg) "	8.9	9.2	14.3
Calcium (Ca) "	316	210	309
$CaCO_3$ Equivalent to Ca "	790	525	773
Sulfur (S) "	128	30	88
Sodium (Na) "	30	13	24
Chlorin (Cl) "	62	32	62
Total Solid Matter "	1428	739	1223

pears to be greater than that from soils growing non-legumes. The comparative effect of nitrogenous fertilizers on the drainage losses of nitrogen has not been satisfactorily determined. The amount of sulfur removed by drainage is comparatively large, while the removal of phosphorus is practically negligible.

GREEN MANURES

The value of organic matter in the soil, the plant nutrients contained in crops and the nitrogen which legumes may secure from the air have had consideration, and all of these are important in a consideration of green manures.

218. Green Manures. Green manures are crops turned under green for soil improvement. They often serve first as cover crops or for pasture and hay and afterward for green manure. Large amounts of organic matter are added to the soil when good growths of green manure crops are turned under while the nutrients in the organic matter,—nitrogen, phosphorus, potassium, calcium, etc.,—are returned to the soil. When the green manure crop is a legume, additional nitrogen from the air may be added. Green manures tend to maintain or increase the organic matter and the nitrogen content of the soil and may also serve a useful purpose by taking up other soluble nutrients that might otherwise leach away and be lost. In some cases crops are planted especially to produce green manure for plowing under, but in most systems of farming some use is made of the crop for pasture or for hay and the after-growth plowed under. An increasing appreciation of green manures is apparent.

219. Crops for Green Manure. Pieters[23] finds that green manuring is practiced to some extent in all parts of the United States except the Great Plains area and the Rocky Mountain area where a lack of moisture is a limiting factor. Green manuring is most common in connection with the production of cotton, corn, and potatoes and is practiced to some extent with sugar beets.

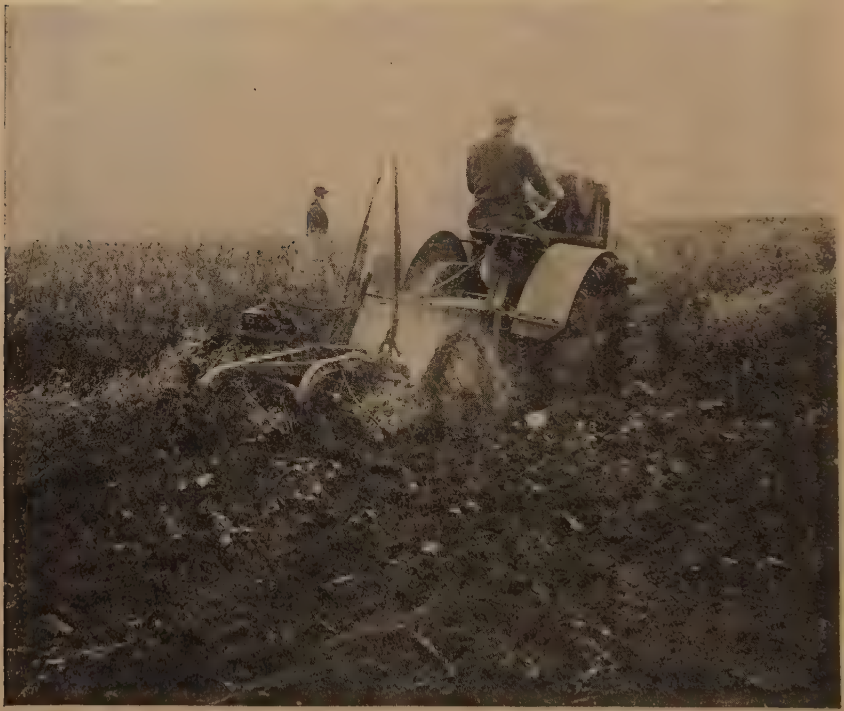

FIG. 56.—Plowing under a green manure crop of Hubam clover in October, seven months after seeding. The clover was seeded in winter wheat. *Under what conditions is this clover preferable to the biennial type?*

In the cotton belt green manure crops are advocated as winter cover crops and companion crops. Legume crops used for green manuring in the cotton belt are hairy vetch, crimson clover, bur clover, sweet clover, cowpeas, velvet beans, peanuts, beggarweed, and, occasionally, soybeans. Among the non-legumes used are rye, oats, and sorghum. The use of a particular crop for green manure depends on local conditions and the crop to be grown following.

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[23] Pieters, A. J.—*Green Manures*, p. 281. John Wiley and Sons. New York. 1927.

In the corn belt green manure crops are becoming more common. Winter cover crops are not so generally advocated as in the cotton belt. Red clover is widely used in the rotation, but the crop recognized as having the greatest value for green manure purposes is sweet clover. In the eastern part of the corn belt crimson clover and vetch are used. Rye is used rather extensively in certain sections. Buckwheat is also often used and winter wheat occasionally.

In the potato sections the same green manure crops are used as for corn except that sweet clover is not widely used, since the liming which often is necessary for sweet clover is likely to increase the damage from potato scab.

In the Pacific Northwest oats and vetch are commonly seeded together in the fall, pastured, and plowed down in the spring. Vetch is the outstanding green manure crop of the section; some sweet clover and bur clover are used.

Green manuring is a common practice in orchards everywhere, including citrus and pecan orchards.

220. Seed Injury from Green Manures. In the first stages of decomposition of green clover numerous fungi develop, some of which are very destructive to seedlings. Oil seeds as a class are very easily damaged,[24] while strachy seeds, on the contrary, are very resistant. Cotton seeds and soybeans are examples of seeds extremely sensitive to green manuring. The damage is confined largely to the first stages of decomposition. Experimental evidence shows that 2 weeks after green manure is incorporated into the soil it does not cause any serious injury to the germination of oil seeds.

221. Green Manures and Soil Acids. Miller[25] found that green manures turned under either fresh or dry did not increase the soil acidity, although a crop containing much sugar (sorghum) increased the acidity for a few weeks, after which there was a decrease to practically that of the untreated plot.

Ames and Schollenberger[26] found that in general, plowing under green manures, both dry and fresh, lowered the lime requirement in field trials, though green soybean hay increased the lime requirement somewhat.

White[27] found that green manures, both legumes and non-legumes, either dry or fresh, added, to soil jars reduced the lime requirement at first so that it was lower at the end of 3 months than pots not treated; but by the end of 9 months the lime requirement had increased so that the green manured jars showed a slightly higher lime requirement than the check. Non-legumes increased the acidity more than the legumes.

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[24] Fred, E. B.—"Relation of Green Manures to the Failure of Certain Seedlings." *Jour. Agr. Res.* Vol. 5, p. 1175. 1916.

[25] Miller, M. F.—"The Effect of the Addition of Organic Matter to the Soil upon the Development of Soil Acidity." *Mo. Agr. Expt. Sta. Bul. 147.* 1917.

[26] Ames, J. W., and Schollenberger, C. J.—"Liming and Lime Requirement of Soil." *Ohio Agr. Expt. Sta. Bul. 306.* 1916.

[27] White, J. W.—"Soil Acidity as Influenced by Green Manures." *Jour. Agr. Res.* Vol. 13, pp. 171-197. 1918.

Pieters[28] has summarized the experimental evidence on the effect of green manures on the lime requirement of the soil and concludes that when properly turned under there is probably little danger that the quantities of green manure likely to be plowed under on farms in the United States will exert any lasting effect in increasing the lime requirement.

222. Relative Root and Top Growth. In general, the biennial and perennial legumes have between 24 and 34 per cent of their dry weight in the roots; annual legumes between 6 and 20; and the annual grasses between 4 and 12 per cent. These proportions vary rather widely. The nitrogen content of the roots is lower than in the top portion of the plant. When the plant is cut for hay, some of the soil nitrogen will be found in the hay in addition to that taken from the air. The biennial and perennial legumes cause the least reduction in soil nitrates when used in this way. Pieters,[29] assuming that two-thirds of the nitrogen of a crop came from the air, estimates that when the hay crop is removed and the roots and stubble plowed under an average crop of red clover takes 2.3 pounds of nitrogen per acre from the soil; alfalfa, 3.4; sweet clover, 6.3; crimson clover, 9.2; vetch, 13.2; cowpeas, 14.7; soybeans, 13.7, and field peas, 17.2 pounds.

Duggar[30] found that, as an average for six varieties of cowpeas, for each 100 pounds of crop removed as hay, there were 15.5 pounds of fallen leaves and leaf stalks and 21.1 pounds of roots and stubble, or a total of 36.6 pounds left on the ground.

Schultze[31] found that when the weight of the tops was taken as 100 the weight of the roots of red clover was 133.3 in the fall of the first year, 139.4 in the early spring of the second year, 33.6 in late spring, and 18.2 in the fall of the second year.

In a similar way he found that with peas, when the top growth was taken as 100, the root growth was 60 as they were beginning to elongate, 12.7 at the end of the blooming period, and 6.4 in the fall. The relation in the different small grains was very similar; winter wheat was 47.2 at the stooling stage, 10.5 in the milk stage, and 9.2 when ripe.

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[28] Pieters, A. J.—*Green Manuring Principles and Practice*, p. 114. John Wiley and Sons. New York. 1927.

[29] *Ibid.*, p. 76.

[30] Duggar, J. F.—"The Cowpeas and Velvet Bean as Fertilizers." *Ala. Agr. Expt. Sta. Bul. No. 120*, p. 135. 1902.

[31] Schultze, B.—*Wurzelatlas.* Paul Parley. Berlin, 1914.

223. Availability of Green Manure Nitrogen. Lohnis [32] has studied the availability of the nitrogen of different green manures. He found that generally young materials in small amounts gave higher immediate returns than larger amounts of old material. Cowpeas were an exception to this rule and gave increasing nitrogen with increasing age; frozen cowpea plants had the highest efficiency. The average availability of green manure nitrogen was from 50 to 80 per cent if added to the soil from other plots. He questions whether the effect of green legumes turned under in place is the result of the green manuring or the influence of the legume type of crop.

When green manure crops are turned under in the fall and the land planted the following season to such a crop as corn or cotton, ready availability of the nitrogen may be undesirable; since much of the total amount may be leached away with heavy rains before it can be used. These crops do not require large amounts of nitrogen and other nutrients until relatively late in the season.

Lyon *et al.*[33] report the effect of 6 years of alfalfa cut for hay on the nitrate content of the soil in comparison with timothy. He found that the alfalfa soil contained little or no more nitrates than the timothy soil but that there was a greater accumulation of nitrates later, on the alfalfa soil. He credits this latter increase of the nitrates on alfalfa soil to the fact that the soil under alfalfa has a smaller quantity of non-nitrogenous organic matter. Non-nitrogenous organic matter is used as a source of energy by the organisms which change nitrate nitrogen to other forms.

224. Red Clover in the Rotation. The effect on the yield of corn following the use of the red clover crop in the rotation in various ways, has been determined through a 10-year period at the Morris,[34] Minnesota, substation. Where both crops of clover were cut for hay, the average yield of corn was 44.2 bushels per acre; the clover pastured all season, 46.3 bushels; the first clover crop cut for hay, second pastured, 45.0 bushels; first crop cut for hay, second plowed under, 42.7 bushels; first crop clipped, second plowed under, 44.2 bushels.

225. Green Manure Yield Summary. Pieters [35] has brought together the results of green manuring studies in different parts of the country. In a one year comparison at the Alabama Station, corn after corn produced 13.6 bushels per acre; after velvet bean stubble, 17.9 bushels; and after velvet beans plowed under, 25.9 bushels.

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[32] Lohnis, F.—"Nitrogen Availability of Green Manures." *Soil Sci.* 22, No. 4, pp. 253-290. 1926.

[33] Lyon, T. L., Bizzell, J. A., and Wilson, B. D.—"An Inquiry into the Reason for the Large Accumulation of Nitrates in Soil Following the Growth of Clover or Alfalfa." *Jour. Amer. Soc. Agr.* Vol. 16, No. 6. pp. 403-404. June, 1924.

[34] Miller, P. E.—*Report of the West Central Expt. Sta. Morris, Minn.* 1925.

[35] Pieters, A. J.—*Green Manuring*, p. 162. John Wiley and Sons. New York. 1927.

At the Arkansas Station, corn after cotton produced 25.8 bushels per acre; after cowpea stubble, 33.6 bushels; and after a cowpea crop plowed under, 39.7 bushels.

At the Virginia Station, as an average for a 12-year period the yield of corn in bushels per acre following crimson clover and rye, cut for hay and plowed under, was as follows:

PREVIOUS TREATMENT	BUSHELS PER ACRE
Crimson clover cut for hay	35.18
Crimson clover plowed under	37.48
Rye cut for hay	17.25
Rye plowed under	8.95
Check	13.24

The yields of wheat through the same 12-year period were as follows:

PREVIOUS TREATMENT	BUSHELS PER ACRE
Soybeans cut for hay	21.09
Soybeans plowed under	26.02
Buckwheat cut for hay	12.94
Buckwheat plowed under	17.42
Check	16.09

At the New Jersey Station, with corn grown annually on the same land but with a winter cover and green manure seeded on the corn at the last cultivation, the average yields of corn for the period 1908-1921, were as follows:

MANURE PER ACRE	WINTER COVER CROP AND GREEN MANURE	
	Winter Rye	Legume
No manure	23.3	35.9
One-half ton	28.3	39.9
One ton	29.9	37.4
Two tons	28.1	38.2

At the Central Experiment Farm, Ottawa (Can.), fodder corn was grown following small grains with red clover seeded in the grain and plowed under; also after small grain without clover. The yields in tons per acre were as follows:

PRECEDING CROP	CLOVER IN SMALL GRAIN	NO CLOVER IN SMALL GRAIN
Wheat	22.80	16.40
Barley	23.60	17.36
Oats	20.40	15.00

At the New Jersey Station the seeding of a legume catch crop following the harvest of winter wheat and plowed down in time to seed to wheat again the same fall gave an average yield of wheat through a 12-year period of 18.1 bushels per acre as compared with a yield of 11.6 bushels where no legume catch crop was seeded. The average yield of winter rye was increased from 16.9 bushels to 22.6 bushels by the same treatment.

In summarizing the results secured from green manures, Pieters concludes that the greatest response has been secured with hoed crops such as corn, and it is for such crops that green manures are to be recommended in the United States. He also points out that there is a marked residual effect from green manure crops and that this must be considered in determining the real profits from the practice.

BARNYARD MANURE AND CROP RESIDUES

226. Barnyard Manure. Attention has already been directed to the plant nutrients required for normal plant growth (97) and to the amount removed from the soil with each crop produced (208). The fact that a considerable part of this, when fed to animals on the farm, can be recovered is an important consideration.

The use of barnyard manure for improving conditions for plant growth dates back to very early historic times. In general, it may be said that the value of manure is more fully appreciated in the older settled regions where conservation of soil nutrients has long been necessary than in the newer agricultural sections. In some countries human waste as well as that from animals is carefully conserved and applied to the land.

227. Nutrients in Crops Recovered in Manure. About one-third of the organic matter in the crops fed can be recovered in the manure. The amount of the plant nutrient recovered depends on a great many factors among which are the age and kind of animal and the nature of the feed.

Hopkins[36] found that with milk cows 80.32 per cent of the nitrogen consumed in the feed was recovered in the manure; 73. 34 per cent of the phosphorus, and 76.02 per cent of the potassium. He also found that of the nitrogen recovered 35.56 per cent was in the solid manure and 44.76 per cent in the liquid; of the phosphorus, 72.33 per cent in the solid, and 1.01 in the liquid, and of the potassium, 16.7 in the solid and 59.32 per cent in the liquid. Other workers have reported manure from beef cattle containing slightly more nitrogen, considerably less phosphorus (55 per cent of that in the feed) and the same amount of potassium. Ohio[37] reports sheep manure containing 64 per cent of the nitrogen, 79 per cent of the phosphorus, and 97 per cent of the potassium contained in the crops fed.

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[36] Hopkins, C. G.—*Soil Fertility and Permanent Agriculture*, p. 201. Ginn and Co. New York. 1910.

As an average each ton of mixed stable barnyard manure is considered to contain approximately 10 pounds of nitrogen, 5 pounds of phosphoric acid (equivalent to 2.2 pounds of phosphorus), and 10 pounds of potash (equivalent to 8.3 pounds of potassium).

Hart[38] states that the amount of manure produced per day for 1,000 pounds live weight of different animals is: sheep, 34.1 pounds; pigs, 56.2 pounds; cows, 74.1 pounds; horses, 48.8 pounds.

228. **Animal Manures Differ Widely.** Beal[39] describes the manures produced by different animals as follows: sheep manure contains a small amount of water and is the richest manure produced by any of the common farm animals. It ferments rapidly with the development of a great deal of heat. Ammonia is very likely to be lost. Horse manure is dry, ferments very rapidly, and is even more likely to lose ammonia than sheep manure. Liquid manure is especially rich in plant nutrients and requires careful management. Hog manure varies widely in composition depending upon the nature of the food given the animal. It is usually rich, containing a high percentage of water, and generates little heat in decomposition. Manure of cattle is generally poorer than that of other farm animals as it contains a high percentage of water. It decomposes slowly and develops but little heat. Poultry manure is rich in all fertilizing elements, especially so in nitrogen. It loses nitrogen very quickly by fermentation, especially when allowed to accumulate in quantity.

229. **Loss from Manure by Weathering.** Ohio[40] reports that manure exposed for 3 months lost by weathering 22.15 per cent of the ash, 35.5 per cent of the organic matter, 22.46 per cent of the phosphorus, 51 per cent of the potassium, 35.6 per cent of the total nitrogen and 59 per cent of the soluble nitrogen.

Similar losses were reported by Lipman and Blair[41] and by Vorhees[42] at the New Jersey Station.

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[37] Thorne, C. E.—"The Maintenance of Fertility." *Ohio Agr. Expt. Sta. Bul. 183.* 1907.

[38] Hart, E. B.—"Getting the Most Profit from Manure." *Wis. Agr. Expt. Sta. Bul. 221.* 1912.

[39] Beal, W. H.—"Barnyard Manure." *U. S. Dept. Agr. Farmers Bul. 192*, pp. 5-32. 1904.

[40] Ames, J. W., and Gaither, E. W.—"Barnyard Manure." *Ohio Agr. Expt. Sta. Bul. 246*, p. 737. 1912.

[41] Lipman, J. G., and Blair, A. W.—"Investigations Relative to the Use of Nitrogenous Plant Food. 1898-1912." *N. J. Agr. Expt. Sta. Bul. 288*, pp. 16-126. 1916.

[42] Vorhees, E. V.—"Losses in Farm Manure." Part I. *N. J. Agr. Expt. Sta. Bul. 150.* 1901.

230. Livestock *vs.* Grain Farming. Fippin[43] states that animals destroy from half to nine-tenths of the organic matter in the feed consumed as it is burned up in the body process and expended as energy. He states that a further large loss occurs in the handling of the manure, and that it is entirely possible to maintain the organic matter in the soil without animal husbandry. He states: "On very poor soils animal husbandry may be bad practice. It may be justified by larger profits from the animal product by means of which the loss of organic matter can be made up from other sources."

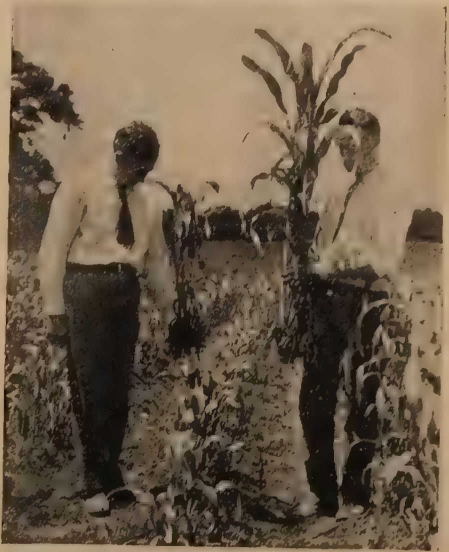

FIG. 57.—Representative hills of corn from adjoining rows. The greater growth of the plants at the right has resulted from the use of 150 pounds of 2-12-4 fertilizer per acre. *On soils which respond to fertilizer what will determine the crop to which the fertilizer should be applied? What will determine the kind of fertilizer to be used and the amount per acre?*

A sixteen-year test of livestock *vs.* grain farming systems has been reported from the Ohio Station.[44] A rotation of corn, soybeans for seed, wheat, and clover has been followed. Crops, except wheat grain, produced on the land devoted to the livestock farming system were fed to cattle running loose in a covered shed. The straw was used for bedding and the manure was usually spread on the clover to be plowed for corn. Fifteen and five-tenths tons of manure have been applied annually under the livestock system. In the grain system, the corn, soybeans, and wheat were all sold and all roughage, including the clover crop, was plowed down for soil improvement. In addition to this, in both systems, two tons of ground limestone and 400 pounds of 16 per cent super phosphate on corn and 300 pounds super phosphate on wheat have been used. The livestock system gave increases in yield over the grain system as follows: 6.8 bushels of corn, 3 bushels of soybeans, and 3.7 bushels of wheat, as a 16-year average. The manure produced from feeding the two leguminous crops together with the other material was very high in fertilizing value. Each ton of manure applied carried 15.2 pounds of nitrogen, 3.9 pounds of phosphoric acid, and 11.6 pounds of potash.

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[43] Fippin, E. O.—"Livestock and the Maintenance of Organic Matter in the Soil." *Jour. Amer. Soc. Agron.*, Vol. 9, No. 3, p. 105. 1917.

[44] Williams, C. G.—"Forty-fifth Annual Report of the Ohio Agricultural Experiment Station." *Ohio Agr. Expt. Sta. Bul. 402*, p. 15. 1927.

231. Crops to Which Manure Should Be Applied The Ohio Station[45] reports that, as an average for an 11-year period, the increase from manure applied to different crops in the rotation was as shown in Table *231a.*

231a. Value of increase from applying manure to different crops. Ohio.

PLOT	CROPS RECEIVING PHOSPHATED MANURE	11-YEAR AVERAGE INCREASE PER ACRE				VALUE OF INCREASE PER ROTATION
		Corn	Oats	Wheat	Clover	
		Bushels			Pounds	Dollars
32	Corn and wheat[a]	16.57	6.95	11.42	1,078	39.59
33	All on corn	19.95	8.05	9.44	815	37.46
35	All on wheat	13.83	5.72	13.30	1,259	41.36
36	All on clover	15.03	4.16	5.75	1,313	30.66

[a] One-half to each.

Lyon[46] determined the effect of applying manure to the grain crops as compared with applying it to the hay crops in the rotation. The results are given in Table *231b.* The rotation consisted of corn, wheat, oats, followed by three years in hay; yields are average for one complete rotation.

231b. Manure applied to grain and hay crops. New York.

MANURE TREATMENT	AVERAGE YIELD PER ACRE			
	Bushels			Pounds
	Corn	Oats	Wheat	Hay
15 tons to corn	73.9	40.6	38.6	5550
5, 5, 5 tons to hay crops	68.6	34.7	40.1	6280
10, 10, 10 tons to hay crops	72.6	37.2	42.4	7077
30 tons to corn	80.1	41.9	44.9	5550

232. Method of Applying Manure to Crops. Tinline[47] compared various methods and times of applying fresh manure on wheat, oats, and barley. Manure was applied at the rate of 12 tons per acre in each case; results are given in Table *232a.*

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[45] Williams, C. G.—"Forty-fourth Annual Report of the Ohio Agricultural Experiment Station." *Ohio Agr. Expt. Sta. Bul. 392*, p. 21. 1926.

[46] Lyon, T. L.—"Experiments in Fertilizing a Crop Rotation." *N. Y.* [*Cornell*] *Agr. Expt. Sta. Bul. 399*, pp. 19-30. 1919.

[47] Tinline, M. J.—"Cultural Experiments." *Canada Expt. Farms. Scott* (*Sask.*) *Sta. Rept. Supt.*, p. 42. 1922.

232a. Method and time of applying barnyard manure. Canada.

Treatment	Yield per Acre—7-Year Average—Bushels		
	Wheat	Barley	Oats
Rotted manure in spring before plowing....	26	28.8	58.5
Rotted manure in fall before plowing	23.3	27	52.6
No manure, burn stubble, fall plow	20.8	23.7	52
No manure, disk stubble, fall plow	21	22.9	51
Rotted manure after seeding on fall plowed land	19.5	20.3	48.9
Fresh manure in winter on fall plowed land.	19	18.3	28.0
No manure—fall plowed	18.3	17.8	43.5

Stevenson and Brown [48] found as a 5-year average that 6 tons of manure plowed under gave 63.53 bushels of corn per acre; disked in after plowing, 64.29 bushels; and cultivated in after corn was up, 60.2 bushels. Yields of oats and clover in the rotation were similarly affected.

Taliaferro and Patterson [49] secured results, averaging two crops of corn and one of wheat which indicated that harrowing in fresh manure gave better results than plowing it under. Where well rotted manure was used, the yields were practically equal.

McKillican [50] found that manure plowed under on fall plowing has given greater yields than top dressing, while in the case of spring plowing, top dressing gave greater yields than plowing under. Differences in labor costs should also have consideration.

Both rotted and composted manure, plowed under at the rate of 12 tons per acre either in the fall or spring, considerably increased the yields of small grains whereas both rotted and unrotted manure applied as a top dressing had no immediate value except in the case of wheat. Fall applications of manure have resulted in greater yields than either spring or winter applications.

Shoesmith [51] compared top dressing and plowing manure under for wheat, clover, and corn. The yields for top dressing were: wheat, 38.4; clover, 2.67 tons; corn, 42.9 bushels. Where the manure was plowed under, the yields were: wheat, 41.7; clover, 2.51 tons; corn, 45.3 bushels.

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[48] Stevenson, W. H., and Brown, P. E.—"Rotation Experiments on the Wisconsin Drift Soil Area with Manure." *Iowa Agr. Expt. Sta. Bul. 167*, p. 475. 1916.

[49] Taliaferro, W. T. L., and Patterson, H. J.—"Stable Manures." *Md. Agr. Expt. Sta. Bul. 122*, pp. 121-138. 1907.

[50] McKillican, W. C.—"Interim Report for the Years Ending Mar. 31, 1921." *Canada Expt. Farms. Brandon (Man.) Farm Rpt. Supt.*, pp. 32-33. 1921.

[51] Shoesmith, V. M., and Spragg, F. A.—"Report of Division of Farm Crops." *55th Ann. Rpt. State Board of Agr.*, Mich. Agr. Expt. Sta., p. 286. 1916.

233. Time to Apply Manure. Taliaferro and Patterson[52] at the Maryland Station, applied manure in different seasons of the year on sod land before plowing for corn. Corn yields reported are an average of 4 years and the wheat for 2 years.

233a. Applying manure at different seasons. Maryland.

	FRESH MANURE		ROTTED MANURE	
	Corn	Wheat	Corn	Wheat
	Bushels			
Summer—July	82.8	20.0	71.6	22.0
Fall—November	69.1	18.4	68.0	17.3
Winter—January	58.2	17.9	...	...
Spring—March	57.5	17.8	61.4	18.0

Ponsonby[53] compared the results obtained from fall and spring applications of 20 tons of manure per acre annually on potatoes, mangels, and turnips. The spring application of manure gave 9 per cent more potatoes, 10 per cent more mangels and 23 per cent more turnips as a 5-year average from 1912 to 1916.

234. Light *vs.* Heavy Application. Wiancko and Jones[54] report experiments conducted on second bottom silt loam soil underlaid at a depth of 2 to 4 feet by a deep bed of gravel. This soil was fine in texture, well supplied with organic matter, and in a good state of fertility when the experiment was begun. The comparison was for a period of 27 years, from 1890 to 1917. A moderately heavy and a light application of manure was made for each crop. The average value of the increase from the manure was $16.44 per acre for 4.7 tons annually and $12.99 for 2.7 tons annually, using prices prevailing in 1918 when the report was issued.

234a. Rates of applying manure—40 years' results. Penn.

PLOT	TREATMENT	BUSHELS			POUNDS
		Corn	Oats	Wheat	Hay
16	Manure, 6 tons	56.3	42.1	23.8	3804
18	Manure, 8 tons	54.6	43.0	24.5	4117
20	Manure, 10 tons	58.2	44.4	25.9	4225

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[52] Taliaferro, W. T. L., and Patterson, H. J.—"Stable Manures." *Md. Agr. Expt. Sta. Bul. No. 122*, pp. 121-138. 1907.

[53] Ponsonby, E.—"Autumn versus Spring Manuring," *Ireland Dept. Agr. and Tech. Instr. Jour.*, Vol. 18, p. 150. 1918.

[54] Wiancko, A. T., and Jones, S. C.—"The Value of Manure on Indiana Soils." *Ind. Agr. Expt. Sta. Bul. 222*, pp. 9-12. 1918.

Gardner[55] applied manure at different rates in a rotation of corn, oats, wheat, and hay. His results are given as an average of 40 years in Table *234a.*

235. Annual Application *vs.* Once in Four Years. Hutcheson and Wolfe[56] report 7-year results, from 1909 to 1916, from applying the same total amount of manure annually as compared with once in a 4-year rotation of corn, wheat, clover, and grass.

TREATMENT	7-YEAR AVERAGE YIELD OF CORN	
	Bushels	Increased Bushels Due to Manure
Four tons manure annually	65.52	20.29
Sixteen tons once in four years	61.94	16.71
No manure	45.23	....

236. Calculated Ton Value of Manure. Every ton of manure product has a definite money value,—the value of the increase in crop yields resulting from its use. Stevenson *et al.*[57] report each ton of manure has a value of $1.97 as measured from the average increase in yield of all crops on 43 different experimental fields in Iowa located on 16 different soil types. Eight tons of manure was applied per acre once in 4 years and the crop prices used were the average for the years 1913-1922. The value of the manure can readily be calculated on the basis of crop prices for any particular period of years.

Snyder and Osborn,[58] reporting on studies in western Nebraska, state that the use of barnyard manure did not increase the yield sufficiently to pay for the application of the manure, probably because under these conditions water rather than plant food is the factor controlling production. However, they state that the use of manure is advisable to guard against deficiency of humus.

237. Crop Residues. The crop residues generally left to be turned under are stalks and straw. The plant nutrients contained in this material returned to the soil when the residues are plowed under has been given. The value of this material has sometimes been calculated from its content of these nutrients. However, the actual value depends not only on the nutrients contained in the material but also on the richness of the soil in these substances and in organic matter, also

[55] Gardner, F. D., Noll, C. F., and Lewis, R. D.—"Forty Years' Results with Fertilizers." *Pa. Agr. Expt. Sta. Bul. 175.* 1922.

[56] Hutcheson, T. B., and Wolfe, T. K.—"Fertilizers and Their Relation to Crop Production in Virginia." *Va. Agr. Expt. Sta. Bul. 221,* p. 30. 1919.

[57] Stevenson, W. H., *et al.*—"The Economic Value of Farm Manure as a Fertilizer on Iowa Soils." *Iowa Agr. Expt. Sta. Bul. 256.* 1926.

[58] Snyder, W. P., and Osborn, W. M.—"Rotations and Tillage Methods in Western Nebraska." *Nebr. Agr. Expt. Sta. Bul. 155.* 1915.

on the moisture supply and the results of complicated changes necessary before the materials in the manure become available. In some sections certain of these materials have proven detrimental to succeeding crops. Many workers have shown that straw turned under, particularly in large amounts, may have a depressing effect on the nitrates in the soil and on the yield of succeeding crops. Martin[59] suggests that this is due to the fact that under such conditions the nitrates are probably utilized by the increased numbers of bacteria that accumulate in the presence of a large supply of carbonaceous matter such as straw.

FIG. 58.—The remains of an enormous strawstack,—one of many. *Of what value is the straw of small grain when returned to the soil at the rate of one to two tons of dry matter per acre?*

Tinline[60] measured the influence of burning stubble for a period of 7 years at the Scott station in Saskatchewan, Canada, where the stubble land had been in a mellow condition as a result of a thorough summer fallow the summer before. The average yield for 7 years shows a difference of 2.5 bushels in favor of burning stubble in the spring and seeding at once as compared with spring plowed stubble. Burning in the fall and disking gave approximately the same yield as burning and plowing but 4.7 bushels less than spring burning and disking.

238. Effect of Plowing Under Corn Stalks and Wheat Straw on the Yield of Corn and Wheat. Corn stover and wheat straw

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[59] Martin, T. L.—"Effect of Straw on Accumulation of Nitrates and on Crop Growth." *Soil Sci.*, Vol. 20, p. 164. 1925.

[60] Tinline, M. J.—"Cultural Experiments." *Canada Expt. Farms. Scott (Sask.) Sta. Rpt. Supt.*, p. 38. 1922.

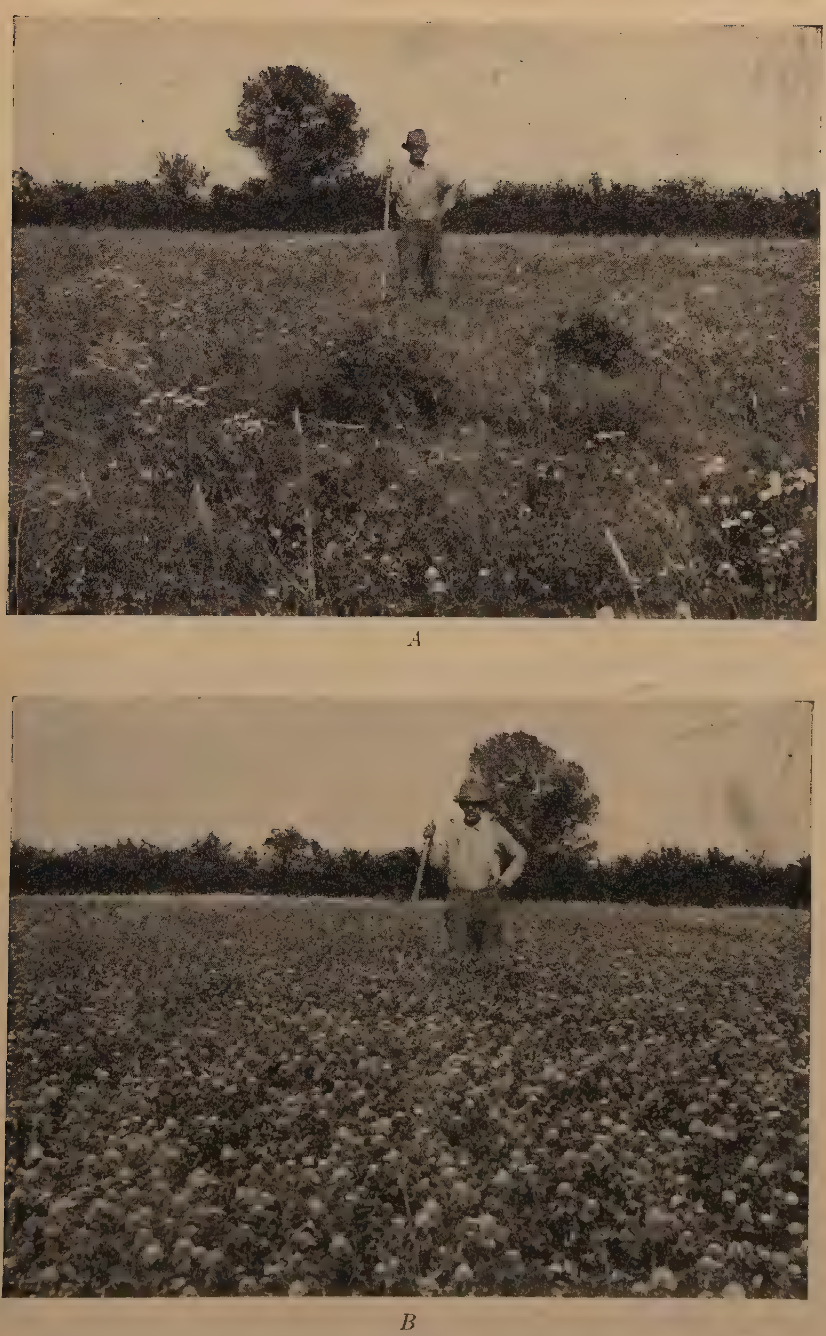

Fig. 59.—*A*, the growth of clover without the use of phosphate fertilizer. *B*, the growth under similar soil conditions with phosphate. *Consider the extent to which the increased yields resulting on many soils from the use of phosphate are due to the increased growth of the legume used in the rotation.*

have been plowed under at the Morris[61] Substation in Minnesota through a series of years. The average yield of corn in a corn and wheat rotation for a 10-year period in which none, 1 ton, and 2 tons of wheat straw were plowed under was 39.1, 40.9, and 40.5 bushels per acre, respectively. The 10-year average yield of the wheat from similar amounts of corn stover was 17.9, 19.2, and 20.2 bushels, respectively. The residues were plowed under at the given rates in 1916, 1917, 1918, and 1919, but not since then until 1924.

Commercial Fertilizers

239. Commercial Fertilizers. In some parts of the country commercial fertilizers are a very important means of increasing crop yields. The use of fertilizers may make the raising of crops profitable when not profitable otherwise, especially where plant nutrients are deficient and this deficiency is the limiting factor in the growing of crops. The application of commercial fertilizers will not correct unfavorable growth conditions, although they may aid at times in avoiding the injury due to these unfavorable conditions.

The application of fertilizers does not always give an increase in yield and often it fails to return a profit. The advisability of making applications of commercial fertilizers depends on several factors among which the more important are the natural productivity of the soil, the length of the growing season, the nature of the crop grown, the cost of the fertilizer, and the relative importance of other limiting factors, particularly weather conditions.

240. Natural Productivity of the Soil. Where an abundance of rainfall makes leaching a vital problem, even though the same care is used in the rotation of crops and in farming as in other sections, soils which receive the heavier rainfall will lose their plant food more rapidly and will be more likely to be benefited by the application of commercial fertilizer than sections of more limited rainfall. Soils which have become depleted in plant nutrients, or are naturally lacking in these elements, usually give a greater return from commercial fertilizer than those well supplied.

241. Character of the Crop. Quite often it is profitable to use commercial fertilizers on one crop in the rotation when it may not be advisable on other crops. Natural conditions may supply sufficient amounts of nutrients for one crop but not for another which may make heavier demands on the soil for these elements. It is often profitable to apply fertilizer to wheat when returns from other crops do not justify similar expenditures. The feeding ability of a crop, its market value, and the amount and time of applying farm manure, are often determining factors in fertilizer use.

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[61] Miller, P. E.—*Report of West Central Experiment Station*, Morris, Minn. 1925.

242. Length of the Growing Season. Fertilizers may be used to modify the length of the growing season required by the crop in order to avoid unfavorable growing conditions. Particular types of fertilizers are advocated in the cotton belt on account of their ability to hasten the maturity of the crop and avoid boll weevil damage. Hastening the maturity of a crop by the application of certain fertilizers may also avoid frost injury in the fall. Where rainfall, temperature, or other weather conditions are the limiting factors, fertilizers cannot usually correct these defects and may even accentuate them, injuring the crop rather than benefiting it.

243. Better-known Plant-nutrient Carriers. Hinkle[62] gives the average composition of the materials more commonly used for home mixing of fertilizers, also their relative availability, as shown in Table *243a*.

243a. Average composition of fertilizer materials commonly used.

	PER CENT			AVAILABILITY
	Phosphoric Acid	Nitrogen	Potash	
Super phosphate	16.0			Quick
Basic slag phosphate[a]	17.0			Slow
Raw rock phosphate	28.0			Very slow
Ground bone	22.0	3.5		Very slow
Sulfate of ammonia		20.0		Quick
Nitrate of soda		16.0		Very quick
Dried blood		14.0		Medium
Tankage	7.0	7.5		Slow
Dried fish	6.0	9.0		Slow
Cottonseed meal	2.8	6.2	2.5	Slow
Tobacco stems	1.5	1.5	6.0	Medium
Muriate of potash			50.0	Quick
Sulfate of potash			48.0	Quick
Kainit			12.0	Quick
Ashes, unleached	1.9		5.5	Medium
Ashes, leached	1.4		1.1	Medium

244. Single Nutrients and Complete Fertilizers. In some sections the use of fertilizers carrying only one nutrient has been found most profitable. Superphosphate is probably used in this way more extensively than any other. Extensive experiments have been conducted in nearly all the different states to determine the return which might be obtained from the use of the different fertilizing materials when used alone and in combination. In general, each soil area is a problem in itself and general rules cannot be laid down with reference to the type of fertilizer to use. The results of fertilizer tests in the different states should be consulted.

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[62] Hinkle, S. F.—*Fertility and Crop Production*, p. 215. S. F. Hinkle. Sandusky, Ohio. 1925.

245. Method of Applying Fertilizers. Helm[63] states that in fertilizing corn in Missouri applying fertilizers in the hill or row yields good returns in seasons of abundant rainfall, but in dry seasons there is more danger that the fertilizer may cause the corn to "fire" than when it is applied ahead of the planter with a fertilizer drill (broadcast).

Gile and Carrero[64] state that it is important to apply fertilizers so that all the roots of the plant will be supplied with all of the fertilizing elements. He has shown that a plant is unable to obtain a maximum absorption with only a portion of its root system in contact with the particular fertilizing elements.

Haskell[65] states that under humid conditions, localized applications of fertilizer may be more beneficial and economical than broadcast distribution, but that on the drier soils of the west the benefit from localized applications becomes relatively less as there is a greater danger of over-stimulation of the crop.

McClelland[66] sums up 5 years' results showing that a gain of 7.7 per cent in yield was obtained when the fertilizer was placed around instead of under the corn hill, though in certain years opposite results were secured.

Redding[67] found with cotton that drilling commercial fertilizer in the row gave a yield of 1435 pounds of seed cotton, while broadcasting gave a yield of 1295 pounds.

Garner and Brown[68] obtained a slight increase with tobacco when applying fertilizer in the drill over the increase obtained from broadcasting.

246. Fertilizer Injury to Seed. Hutcheson and Wolfe[69] tested the germination of numerous crop seed when planted with 9 different amounts of fertilizer, on Hagerstown silt loam and Norfolk sandy loam. The average germination of all the seed with few exceptions was higher where the fertilizer was applied broadcast than where applied in the row.

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[63] Helm, C. A.—"Corn in Missouri." *Mo. Agr. Expt. Sta. Bul. 185.* 1921.

[64] Gile, P. L., and Carrero, J. O.—"Absorption of Nutrients as Affected by the Number of Roots Supplied with the Nutrient." *Jour. Agr. Res.* Vol. 9, No. 3, p. 95. April 16, 1917.

[65] Haskell, S. B.—"Methods of Distribution of Phosphorus Fertilizers." *Jour. Amer. Soc. Agron.* Vol. 15, No. 4, p. 151. Apr., 1923.

[66] McClelland, C. K.—"Cotton and Corn." *Ga. Agr. Expt. Sta. Bul. 128.* 1919.

[67] Redding, R. J.—"Cotton Culture." *Ga. Agr. Expt. Sta. Bul. 52.* 1901.

[68] Garner, W. W., and Brown, D. E.—"Fertilizer Experiments with Tobacco." *Md. Agr. Expt. Sta. Bul. 225.* 1919.

[69] Hutcheson, T. B., and Wolfe, T. K.—"The Effect of Fertilizers on the Germination of Seeds." *Va. Agr. Expt. Sta. Ann. Rpt. 1918-19*, pp. 33-37. 1920.

Coe[70] states that fertilizer applications located in direct contact with the hill or drilled with the seed are likely to injure the germination. The injury is modified by various climatic factors. He also found very small amounts of concentrated, readily soluble chemical fertilizers injurious to the seed and seedling. Small applications gave retarded germinations, while larger amounts in some cases largely prevented satisfactory germination. He recommends that the fertilizer be distributed in a ribbon along both sides of the hill.

STUDY QUESTIONS ON CHAPTER VIII

1. What is the situation with reference to the abundance and availability of the different plant nutrients in an average soil in your section? How does the soil lose its plant nutrients?
2. What change in the soil is brought about by grain farming? By a rotation in which a legume is included regularly?
3. With the average cropping system and rainfall of your section, where is the danger of erosion greatest? Why? What precautions need to be taken?
4. How serious would you estimate the loss of nutrients by percolation in your section? What nutrients are most likely to be lost and what can be done to prevent this loss?
5. In general, in the U. S., where are the green manures most needed? Why? Where are they the most used? Why?
6. Give instructions for the use of the best green manure crop or crops in your section.
7. Calculate the effect on the nitrogen, phosphorus, and potassium content of the soil, if all crops produced on a given area of land were fed to cattle and the manure returned to the land. Make allowance for the amounts of the different elements retained by the animals and the amount lost by a three months' storage.
8. What determines the crop to which manure should be applied? When should the application be made?
9. What determines the value of crop residues available to be turned under?
10. What happens in the soil when a large amount of organic material, low in nitrogen, is turned under? Why?

APPLICATION ASSIGNMENTS ON CHAPTER VIII

1. On a certain field of your farm, clover yields well but corn and oats do not. You decide to use fertilizer. What will you use? What makes you think this best?

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[70] Coe, Dana G.—"Effects of Various Methods of Applying Fertilizers on Crops and on Certain Soil Conditions." *Soil Sci.* Vol. 21, p. 20. 1926.

2. Your yields are decreasing in spite of the fact that you are using a good rotation, feeding all crops, and returning the manure to the land. Your neighbors have been getting good yields with commercial fertilizers. What more can you do to maintain the yielding power of your soil?
3. In an effort to save labor you are considering a heavy application of fertilizer every three or four years instead of making a smaller application each year. Is this advisable in your section? Why?
4. Your clover, grown for green manure, has made an exceptional growth and you can expect two tons per acre if cut for hay. Should you cut for hay or turn the whole crop under? What considerations will determine this?
5. A factory offers $2.50 per acre for your corn stalks. They will cut and haul the stalks when the ground is frozen. Will you accept the offer? Why?

CHAPTER IX

PLOWING AND SEEDBED PREPARATION

The tilling of the soil is a fundamental principle of crop production. It is as old as our written history and no one knows how much older. The actual origin of the practice is unknown although various writers point out how it may have originated. One of these writers suggests that probably it came about through the observation that plants grew better on land "rooted up" by wild boars. The advantage a plant had when not surrounded by weeds was probably a big incentive toward tillage.

SOME EARLY IDEAS ON TILLAGE

247. Early Theories. Early writers made many attempts to explain why tillage was beneficial. The recommended intensity of tillage has fluctuated just as any other debatable practice fluctuates if left for man to decide what is best.

Arthur Young[1] reports numerous tests of methods of adding "phlogiston" to the soil. In one test he plowed the ground several times in order to incorporate the maximum amount of "phlogiston," which was at that time supposed to be the food for plants. The results of the plowing test and many of the others did not prove satisfactory as the repeated number of plowings did not yield sufficient increase to cover the increased cost of labor.

Jethro Tull[2] taught that "Tillage is manure" and that by cultivation we were breaking up the soil and separating it into its small particles so that the plants could get them into their "mouths." He taught also that the benefit of manure came from its tendency to pulverize or break up the soil still finer.

Lee,[3] an editor from Augusta, Georgia, presented the view that exhaustion of the soil is promoted by excessive plowing and hoeing. He believed that two-thirds of the tillage in the United States, especially in the southern states, impaired the natural fertility of the soil. He attributed this to the greater oxidation of organic matter on the tilled land and to the leaching of its soluble mineral elements.

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[1] Young, Arthur—"Experiments to Ascertain How Far, and in What Form, Phlogiston is the Food of Plants." *Annals of Agriculture.* (London.) Vol. 1, p. 139. 1790.

[2] Tull, Jethro—*Horse Hoeing Husbandry.* William Corbett. London, England. 1731.

[3] Lee, Daniel—"The Philosophy of Tillage." *N. Y. Agr. Soc. Trans.* Vol. 8, pp. 342-358. 1848.

The importance of deep tillage and subsoiling was suggested by one Goodale.[4] It was his opinion that these practices allowed roots to penetrate deeply in search of food and moisture.

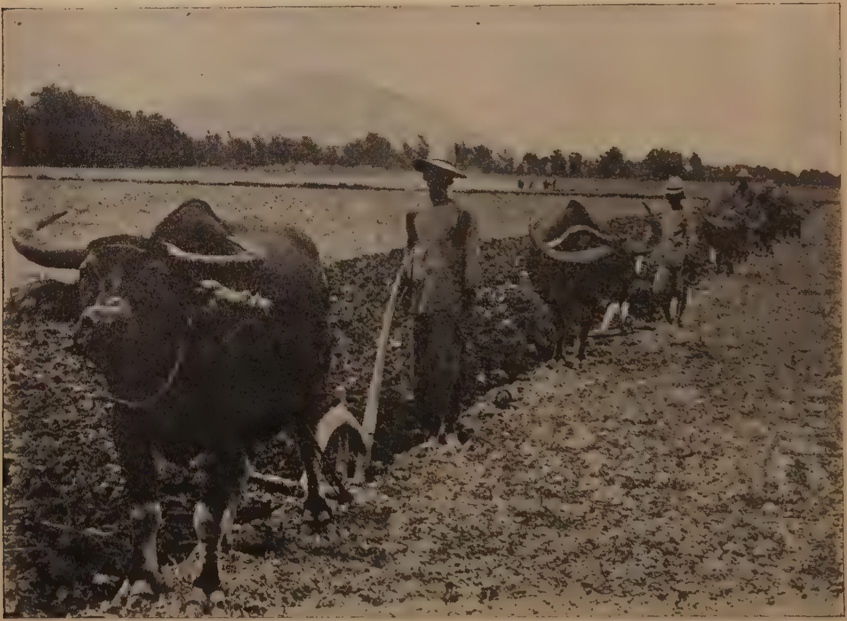

FIG. 60.—The type of plow and of plowing varies greatly in different countries as well as for different soils. *Is there any special relation between the way in which the soil is turned or stirred and the crop yield which results? Why do we plow? Can we reduce production costs by doing less plowing, or shallower plowing than is general, without decreasing crop yields?*

Turner[5] thought the real end in plowing was to put the soil in such condition that the plant might most readily absorb energy from the sun, and the moisture, and other food elements from the air.

METHODS OF SEEDBED PREPARATION

Common methods of seedbed preparation are plowing, listing, and disking. To these may be added special methods used in some sections such as cultivation with a corn or cotton cultivator, and harrowing to loosen the surface only and break down old stalk growth.

[4] Goodale, George L.—"Prize Essay on Underdraining and Deep Tillage." *Abs. of Returns from Agr. Soc. of Maine*, pp. 122-138. 1860.

[5] Turner, J. B.—"On Cultivation of Field Crops and Preparation of Soils." *Abs. of Returns from Agr. Soc. of Maine*, pp. 70-88. 1866.

248. Plows and Plowing. There are several types of plows, varying in size from a single bottom, 8 to 18-inch, to the large gang plows turning many furrow slices at a time. The most common plow is probably the 12, 14 or 16-inch single bottom plow. The plowshare is the part which cuts the furrow slice loose; the moldboard is the curved piece of steel which turns the furrow slice over, and the coulter is the part which cuts the edge of the furrow slice loose, evening the slice. Some plows have a jointer which works on the beam and throws a ribbon from the edge of the furrow slice into the bottom of the furrow so that a smooth piece of work can be done in turning under vegetation.

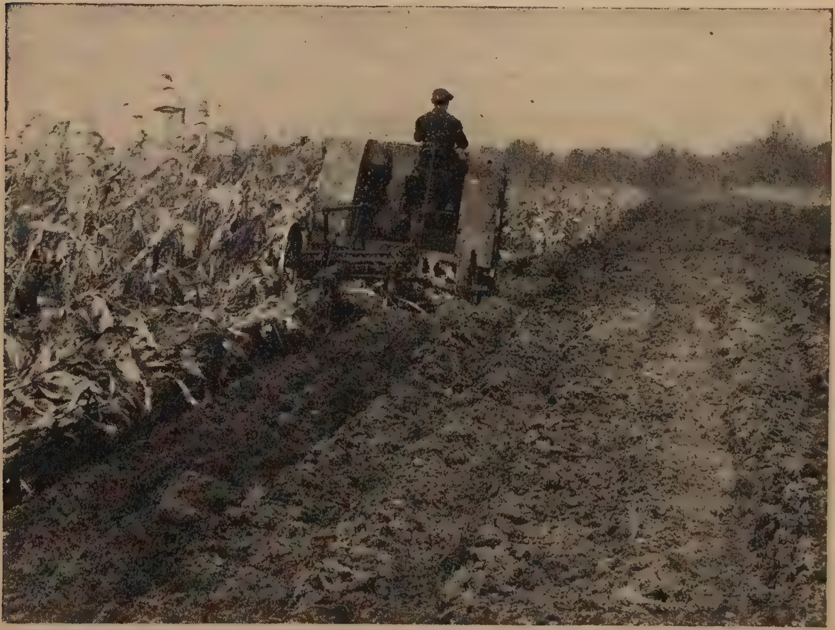

FIG. 61.—Plowing under a very heavy growth of cornstalks and doing a perfect job of covering. In the fight against the European corn borer particular attention has been given to types of plows which are effective in covering cornstalks and other débris.

A plow for use in sod has a long, sloping moldboard which rolls the furrow slice over easily and does very little to break it up. A stubble plow has a short, sharply curved moldboard, which breaks up the furrow slice in turning it over. Between these two are varying degrees of curvature for general use.

A recent plow (tiller) has a pulverizing attachment in place of the moldboard. This consists of a shaft with blades so placed that the furrow slice as it is turned is chopped and pulverized by these revolving blades. It is claimed that it makes a seedbed ready for planting at one operation.

Disk plows are common in certain sections. A large disk takes the place of the share and moldboard of the ordinary plow. It revolves as it cuts and turns the furrow slice. The furrow slice ordinarily is broken up more by the disk plow than by the turning plow. In dry sections the disk plow is used in plowing for wheat. It is not considered good for turning under a rank growth of vegetation.

249. Listers and Listing. The lister is a double moldboard device which throws part of the dirt each way. The share is one piece bent back both ways from the middle so that, together with the moldboard, it looks like a right and a left hand plow welded together on one beam. The lister tears open furrows in the land, throwing a furrow slice each way and leaving the ground ridged. The dirt thrown out makes ridges 4 to 5 inches above the original surface and approximately 15 inches broad. The furrows between the ridges are about the same width and extend as deep below as the ridge is raised above the original surface. In single listing, as described, there is a strip of unstirred soil under each ridge.

Double listing consists of single listing, as above described, then splitting the ridge by going over the field again with the lister. The ridge is split down practically as deep as the first listing so that no soil is left unstirred and the ridges are where the furrows were in single listing.

Single listing may be done in the fall and the ground listed again in the spring. In planting corn and grain sorghums, quite often a lister-planter may be used, which lists the ground and plants at the same operation. Sometimes the ridges are dragged down and flattened somewhat and the crop planted on top of the ridges. Corn on listed ground is usually drilled rather than checked.

250. Disking. Disking is a rapid method of preparing a seedbed. It is used most on land fairly free of vegetation, as it chops up the vegetation but does not cover it well. The disk stirs the soil 3 to 6 inches deep, depending on the firmness of the soil. It will kill weeds and grass that are just starting, but it does not bury weed seeds sufficiently deep to keep them from bothering some time during the season.

251. Other Methods of Seedbed Preparation. Old stalk fields of cotton, corn, or other cultivated crops are sometimes prepared for the next crop by cultivating them. Cultivation stirs up the soil 3 to 6 inches deep, much the same as the disk, but does not cover up the vegetation so much. It is a rapid way of preparing a seedbed.

The harrow, either spike or spring tooth, will prepare a fair seedbed on clean, mellow land that has been in a cultivated crop the previous year. It does not incorporate much organic matter with the soil.

Bedding is a method quite extensively used in the wet sections of the South in preparing a seedbed for corn, cotton, sugar cane, and other crops. Beds are made with the ordinary turning plow. The field is plowed by throwing the desired number of furrows together, thus making a backfurrow in the center of the bed with a dead furrow on either side for drainage purposes. Beds may be made wide enough for any required number of rows.

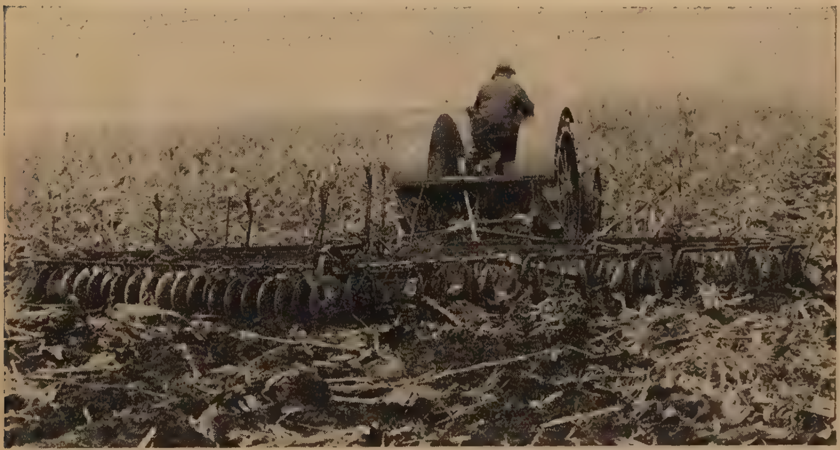

FIG. 62.—One of the most common methods of seeding oats in the corn belt is to broadcast in the standing cornstalks, the seed being covered later by double disking and harrowing. *To what extent and under what conditions can the soil be disked to better advantage than plowed, in the preparation of the seedbed for rowed crops?*

252. Comparison of Costs in Seedbed Preparation. Seedbed preparation is usually recognized as an important item in the cost of producing field crops. This is more important for some crops than for others. The type of machinery used and the number of horses handled per man must have first consideration. Certain soil characteristics and climatic conditions may be of greater importance in a consideration of seedbed costs than is immediately apparent. The data in Table 253 indicates the rate of plowing and other operations in preparing a seedbed in various parts of the United States. Comparison may be made of the rate of plowing sod and stubble and of spring and fall plowing as well as of types of plows. The cost per acre for each operation may be determined from this data. For ordinary purposes man labor on the farm may be roughly estimated at 25 cents per hour and horse labor at half this, or 12½ cents per hour.

253. Acres per Ten-Hour Day for Operations in Seedbed Preparation.[6]

LOCATION AND ITEM	SIZE OF IMPLEMENT	CREW		ACRES PER 10-HOUR DAY
		Men	Horses	
	Plowing			
Corn belt plowing	8″ walking	1	2	1.6
“ “ “	10″ “	1	2	1.7
“ “ “	12″ “	1	2	1.8
“ “ “	14″ “	1	2	1.9
“ “ “	16″ “	1	2	2.0
“ “ “	16″ sulky	1	3	2.7
“ “ “	16″ “	1	4	2.9
“ “ “	24″ gang	1	4	4.1
“ “ “	28″ “	1	4	4.4
Illinois spring plow	14″ sulky	1	3	2.91
“ “ “	16″ “	1	3	2.97
“ “ “	24″ gang	1	4	4.94
“ fall “	14″ sulky	1	3	2.61
“ “ “	16″ “	1	3	2.72
“ “ “	24″ gang	1	5	4.63
Louisiana sod land	12″ walking	1	2	2.11
Texas cotton		1	1.9	2.0
Western New York sod	14″ “	1	3	1.85
“ “ “ stubble	14″ “	1	3	2.0
General U. S. tractor and stubble	7.4 feet	15 horse power		14.0
General U. S. tractor and stubble	11.3 “	25		20.6
General U. S. tractor and stubble	12.3 “	60		24.8
Corn belt; tractor spring plow	2 bottom			6.6
Corn belt; fall plow	2 “			6.5
“ “ spring “	3 “			8.6
	Disking			
Illinois soil, well packed	7 foot disk	1	4	15.1
“ “ “ “	8 “ “	1	4	17.1
“ “ freshly plowed	7 “ “	1	4	14.1
Kansas		1	4.4	10.0
Louisiana	6 to 8 foot	1	4	11.6
	Harrowing			
General U. S. well packed	8 foot spike tooth	1	2	13.4
“ “ “ “ “	16 “ “ “	1	4	36.4
“ “ “ freshly plowed	8 “ “ “	1	2	11.2
“ “ “ “ “	16 “ “ “	1	4	29.3
“ “ “ “ “	8 “ spring “	1	4	13.6
	Listing			
Louisiana 3½ foot rows	Single listing	1	2	5.9
“ 4 “ “	“ “	1	2	7.4
“ 3½ “ “	Breaking middles (Second listing)	1	2	7.0
“ 4 “ “	“ “	1	2	7.7
General U. S. 3½ foot rows	Single listing	1	3	7.5
	Cultivating			
Central Illinois 3⅓ foot rows	1 row riding	1	2	7.8
“ “ 3⅓ “ “	2 “ “	1	3	13.8
“ “ 3½ “ “	2 “ “	1	4	14.9
Western New York	1 “ “	1	2	6.4

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[6] *U. S. Dept. Agr. Yearbook,* pp. 1045-1078. 1922.

254. Draft of Plowing. The cost of preparing the seedbed is greatly increased by deep plowing and by subsoiling, and before considering the yield results from these different practices it will be well to consider the influence of different factors on the draft of plows and the increase in cost of various treatments.

The draft of plows of varying width and in plowing furrows of varying depth is given as follows in *The Thresherman's Review.*[7]

254a. Pull in pounds required to plow at given depths and with given width plows.

Width of Plow	Depth of Furrow			
	4-Inch	6-Inch	8-Inch	12-Inch
10	203	266	329	451
12	257	332	408	560
14	310	399	488	665
16	364	465	567	771
18	417	532	647	876

The draft per square foot of cross section of furrow was determined at the Pennsylvania Station[8] and found to average 1,113 pounds for 12-inch plowing and 724 pounds for 7½-inch plowing.

Illinois reports[9] that increasing the depth of plowing one inch increases the weight of soil turned 300,000 pounds or 150 tons. They estimate that when it costs $2.50 per acre to do ordinary plowing it costs $5.00 for subsoiling and $7.00 per acre for deep tilling (14 inches deep), while dynamiting costs range from $20.00 to $25.00 per acre.

255. Soil Treatment and Draft of Plows. Duley and Jones[10] report that heavy manuring has had a slight tendency to increase the draft of the plow. However, in this connection they say: "It must be stated that the plow draft tends to increase as the soil moisture content decreases and that the manured land contains more soil moisture than the unmanured land. This may have brought the draft on the manured and the unmanured plots nearer together than if these plots could have been plowed with the same soil moisture content. It would seem that with the same moisture content the draft on the manured plots might have been relatively greater."

The use of chemical fertilizers has had practically no effect upon the plow draft.

[7] "The Draft of Plows." *Thresherman's Review*, Vol. 15, No. 8, p. 20. 1906.

[8] Noll, C. F.—"Deep *vs.* Ordinary Plowing." *Penn. Agr. Expt. Sta. Ann. Rpt. 1912-13*, pp. 39-47. 1913.

[9] Smith, Raymond S.—"Experiments with Subsoiling, Deep Tilling, and Subsoil Dynamiting." *Ill. Agr. Sta. Bul. 258.* 1925.

[10] Duley, F. L., and Jones, M. M.—"Effects of Soil Treatments upon the Draft of Plows." *Soil Sci.* Vol. 21, No. 4, p. 287. April, 1926.

256. Type of Plow and Draft. King[11] reports tests on the drafts of plows at the Wisconsin Agricultural Experiment Station, expressed in pounds per square inch of furrow slice, as follows:

	SOD PLOW WITH COULTER	SOD PLOW WITHOUT COULTER
Clover sod, soil dry	8.6	10.8
Clover sod, soil with plenty of water	3.5	4.5

A sod plow had a draft per square inch of furrow slice of 4.45 pounds in comparison with 5.38 pounds for a stubble plow.

King also reports a test in England on different soil types which showed the following pounds of draft per square inch: loamy sand, 5.04; sandy loam, 5.55; moor soil, 6.22; strong loam, 9.72, and blue clay, 12.2.

DEPTH OF PLOWING

257. "Farm the Farm below Your Farm." Deep plowing has been advocated repeatedly in the past and there are many today who feel that farmers generally are plowing much too shallow. A good many logical reasons have been given for deeper seedbed preparation.

A few years ago the slogan "Farm the farm below your farm" was commonly used in discussing plowing. About the time this slogan was being used, two deep tilling machines were put on the market with which it was possible to plow to a depth of from 10 to 16 inches and apparently to make an ideal seedbed.

The subsoil plow was also advocated. This plow did not have a regular moldboard but was run in the bottom of the furrow made by an ordinary plow; it stirred the soil, lifting and breaking it up but letting it settle back in place. With this device the subsoil was aërated and opened up but it was not brought to the surface.

Dynamiting the soil was also advocated to break up the hard layers of subsoil. Holes were bored in checkerboard fashion over the field and a charge of dynamite put in each and set off.

Many experiments have been conducted to determine the soundness of these theories under field conditions.

258. Depth of Plowing and Yield. Noll[12] reports the results of a 4-year comparison of deep plowing (12 inches), and of ordinary plowing (7½ inches) at the Pennsylvania Station. The average yield of crops was as given in Table *258a*.

At Langdon Substation, North Dakota,[13] different depths of

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[11] King, F. H. *Physics of Agriculture*, p. 243. Sixth edition. 1914. Mrs. F. H. King. Madison, Wis.

[12] Noll, C. F.—"Deep *vs.* Ordinary Plowing." *Penn. Agr. Expt. Sta. Ann. Rpt. 1912-13*, pp. 39-47. 1913.

[13] Trowbridge, P. F.—"Report of Langdon Substation 1914 to 1919." *N. Dak. Agr. Expt. Sta. Bul. 134*. 1920.

258a. Depth of plowing test. Pennsylvania.

Crop	No. of Tests	Pounds per Acre	
		7½-Inch Plowing	12-Inch Plowing
Corn	3	4,128	3,957
Barley	1	835	792
Oats	2	1,059	1,086
Wheat	2	1,240	1,281
Alfalfa	3	2,716	2,774
Clover and timothy	2	4,537	4,483

plowing, both in the fall and spring, have been compared through a number of years, 1911 to 1919. The results are given in Table *258b*.

258b. Depth of plowing and yield of wheat, oats, and timothy. North Dakota.

Time and Depth of Plowing	Average Yield per Acre		
	9-Year Wheat	8-Year Oats	7-Year Timothy Hay
Fall, 5 to 6 in.	20.72	53.08	1576
Fall, 12 in.	24.21	58.24	1643
Fall, 3 to 4 in.	21.92	52.29	1217
Spring, 3 to 4 in.	21.10	44.81	1286
Spring, 5 to 6 in.	21.72	41.85	1200

The cost of plowing 12 inches deep was about three times greater than plowing 5 or 6 inches deep.

Illinois[14] reports a 6-year average yield of corn for crops immediately following various depths and times of plowing and a 4-year average for the crop of the second year, in Table *258c*.

258c. Effect of various depths of plowing on first and second crops on the land. Illinois.

Time of Plowing	Depth	6-Year Average	4-Year Average
		First Crop	Second Crop
Fall	12–14 ins.	65.7	63.6
Fall	7 ins.	65.0	63.3
Spring	7 ins.	65.9	62.3
Spring	3– 4 ins.	63.6	60.9

Indiana[15] reports 4 years' data on corn yields with different depths of plowing as follows:

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[14] Smith, Raymond S.—"Experiments with Subsoiling, Deep Tilling, and Subsoil Dynamiting." *Ill. Agr. Expt. Sta. Bul. 258.* 1925.

[15] Latta, W. C., and Ives, R.—"Field Experiments with Corn and Oats." *Ind. Agr. Expt. Sta. Bul. 55*, p. 27. 1895.

	DEPTH OF PLOWING						
	4 Ins.	6 Ins.	8 Ins.	10 Ins.	12 Ins.	14 Ins.	16 Ins.
4-yr. av. yield of corn	33.77	34.19	34.81	34.49	35.00	34.84	34.44

The effect of plowing sod land at different depths for the seeding of oats has been studied by Clark in Canada.[16]

The soil is a sandy loam with a heavy, gravelly subsoil. Plowings were made to a depth of 3, 5 and 7 inches in the fall and 4 and 6 inches in the spring. The average yields of oats for an eleven-year period were: 41.5, 41.4, 39.5, 35.4 and 38.5 bushels, respectively.

Nebraska[17] reports the average yield of winter wheat on land plowed to different depths.

A Spaulding deep tillage implement was used for the 14-inch plowing. The soil was a medium black loam with a water table 200 feet below the surface. Yields are the average of 4 plats each year through a 4-year period, expressed in bushels per acre.

258d. Yield of winter wheat in bushels per acre from early and late plowing to different depths, and from disking. Nebraska.

		3 INCHES	7 INCHES	10 INCHES	14 INCHES
Plowed Aug. 15		13.5	14.3	14.6	14.4
Plowed Sept. 15		12.1	13.4	13.1	13.9
Disked only ...	14.3				

259. Depth of Plowing Summary. The results of depth of plowing experiments are available from a number of stations in addition to those included in the above reports. The more important data for a number of these are summarized in Table *259a*.

260. Subsoiling. An experiment in subsoiling was conducted at the Hays, Kansas, Field Station.[18] Two comparisons were made, one on heavy silt loam from 1907 to 1916, and another on light silt loam from 1909 to 1916. The results expressed in bushels per acre are given in Table *260a*.

Hastings and Letteer,[19] in reporting on experiments in subsoiling at San Antonio, Texas, covering 3-year periods, conclude that neither the moisture content of the soil nor the yield of corn, cotton, or oats was increased by subsoiling.

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[16] Clark, J. A.—"Cultural Experiments." *Canada Expt. Farms. Charlottetown (P. E. I.) Rpt. Supt.*, p. 21. 1926.

[17] Zook, L. L.—"Winter Wheat. Seed Bed Preparation." *Nebr. Agr. Expt. Sta. Bul. 178*, p. 5. 1921.

[18] Chilcott, E. C., and Cole, John S.—"Subsoiling, Deep Tilling, and Soil Dynamiting in the Great Plains." *Jour. Agr. Res.* Vol. 14, No. 11, pp. 481-521. Sept. 9, 1918.

[19] Hastings, S. H., and Letteer, C. R.—"Experiments in Subsoiling at San Antonio." *U. S. Dept. Agr. Bur. Plant Indus. Circ. 114*, pp. 9-14. 1913.

259a. Depth of plowing comparisons in a number of states; yields in bushels per acre except when pounds (#) or tons is indicated.

LOCATION	REFERENCE	CROP	NO. YEARS	3	4	5	6	7	8	9	10	12
Pennsylvania	a	Corn	1					4201#				4065#
Pennsylvania	a	Alfalfa	1					2639#				2552#
New Hampshire	b	Corn	1	14.2T.		26.2T.		29.4T.		28.2T.		
California	c	Wheat 40 trials	3		21.67			29.78				
California	c	Barley 40 trials	3		69.30			75.98				
Mo. Shelbina	d	Wheat	4		16.1			15.4				
Mo. Warrensburg	d	Wheat	4		22.8				24.4			
Oregon	e	Sp. wheat				20.4					21.3	
Washington	f	Wheat	20		28.8		29.1	27.8	28.7			
Arizona	g	Milo	1	416#	494#	468#	468#	468#	650#	910#	624#	468#

[a] *Penn. Agr. Expt. Sta. Ann. Rpt.* 1912/13.
[b] *N. H. Agr. Expt. Sta. Bul. 71.* 1900.
[c] *Calif. Agr. Expt. Sta. Bul. 211.* 1911.
[d] *Mo. Agr. Expt. Sta. Bul. 188.* 1921.
[e] *Ore. Agr. Expt. Sta. Bul. 190.* 1922.
[f] *Wash. Agr. Expt. Sta. Bul. 160.* 1921.
[g] *Ariz. Agr. Expt. Sta. Bul. 84.* 1918.

260a. Subsoiling experiments—ten-year average yield per acre, heavy silt loam soil. Kansas.

	Spring Wheat	Winter Wheat	Oats	Barley	Corn	Kafir	Milo
Heavy Silt Loam Soil							
Not subsoiled	5.4	16.2	15.8	14.8	7.0	19.5	21.6
Subsoiled	5.8	19.6	20.8	14.8	8.8	23.5	21.3
Light Silt Loam Soil—Upland. Garden City							
Not subsoiled	4.5	2.3	11.5	8.8	...	...	...
Subsoiled	4.7	2.4	11.4	8.6	...	...	...

Chilcott and Cole [20] have summarized the results for the Great Plains area of 353 comparisons between subsoiling and ordinary plowing. In 153 cases the subsoiled plats yielded highest, while plats not subsoiled yielded highest in 183 cases.

More important yet is a statement they make with reference to failures in unfavorable years. They state, "There have been a number of cases where crops under both methods were failures. There have been cases where the not subsoiled plot produced a small crop when the subsoiled plot was a total failure. There has been no case in the history of the experiments when the reverse was true." Subsoiling and deep tilling are not recommended as a general practice for the Great Plains as no increase in yield can be expected.

261. Plowing, Subsoiling, and Deep Tillage. Ohio [21] reports a comparison of different depths of plowing and of subsoiling for 12 years. The results are given in Table *261a*. There are two plowings in

261a. Comparison of subsoiling, deep tilling and ordinary plowing. Ohio.

Crop	Ordinary Plowing, 7½″		Deep Plowing, 15″		Ordinary Plowing Plus Subsoiling	
	Grain (bushels)	Straw or Hay (pounds)	Grain (bushels)	Straw or Hay (pounds)	Grain (bushels)	Straw or Hay (pounds)
Corn	61.13	3,251	59.47	3,066	61.33	3,229
Oats	49.00	2,159	49.29	2,048	49.05	2,188
Wheat	31.50	3,488	31.49	3,517	31.65	3,549
Clover	....	5,300	....	5,060	....	5,200

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[20] Chilcott, E. C., and Cole, John S.—"Subsoiling, Deep Tilling, and Soil Dynamiting in the Great Plains." *Jour. Agr. Res.*, Vol. 14, No. 11, p. 499. Sept. 9, 1918.

[21] Williams, C. G.—"Forty-first Annual Report 1921-22." *Ohio Agr. Expt. Sta. Bul. 362.* 1922.

each rotation of 4 years. Subsoil was not brought to the top in subsoiling, while deep plowing brought some to the top.

Similar results are reported on a cold clay loam soil in Cuyahoga County.

Wisconsin reports [22] the influence on the yield of corn, oats, and timothy of plowing to different depths, subsoiling, and deep tilling a silt loam soil. The results are given in Table *261b*.

261b. Depth and time of plowing for corn and oats (nine-year average) and for timothy (five-year average). Wisconsin.

	Corn	Oats	Timothy
Fall plowed 3 in.	56.33	51.22	4096
Fall plowed 6 in.	58.67	52.30	4097
Fall plowed 8 in.	59.02	50.71	4305
Subsoiled 16 in.	58.11	51.90	4252
Deep tilled 16 in.	56.15	48.81	4360
Spring plowed 6 in.	60.68	53.29	4182

Rather extensive comparisons of 7-inch plowing, subsoiling 14 inches deep, deep tilling 14 inches deep, and dynamiting, for corn, soybeans, wheat, and sweet clover are reported from the Illinois Station.[23] All tillage operations were performed in the fall. The soil is a gray silt loam underlaid by a rather impervious layer of tight clay, varying from near the surface to 19 inches below. The results are given in Table *261c*.

261c. Subsoiling, deep tilling, dynamiting, and ordinary plowing compared. Illinois.

Tillage Treatment	Bushels of Each Crop per Acre			
	9-Yr. Corn	7-Yr. Soybeans	6-Yr. Wheat	6-Yr. Sweet Clover Seed
Plowed 7 in.	40.2	16.3	13.5	3.68
Subsoiled 14 in. deep	41.9	16.2	12.9	3.65
Deep tilled 14 in. deep	37.4	15.2	10.8	3.18
Dynamited	40.3	16.4	11.7	4.25

Two dry years included showed 0.5 and 0.6 bushels increase for subsoiling. All others showed decreases. The subsoiling was done once in 4 years. In another field comparing "subsoiled" with "not subsoiled" as an average for 13 years, with 5 comparisons each year, corn on subsoiled land yielded 25.3 bushels, while that on land not subsoiled yielded 26.6 bushels.

[22] Musbach, F. L.—"Farming the Heavy Silt Loams of Central Wisconsin." *Wis. Agr. Expt. Sta. Bul. 347.* 1922.

[23] Smith, Raymond S.—"Experiments with Subsoiling, Deep Tilling and Subsoil Dynamiting." *Ill. Agr. Expt. Sta. Bul. 258.* 1925.

262. Plowing, Deep Tillage, Subsoiling Summary. A number of stations, in addition to those reported, have compared deep tillage or subsoiling with ordinary plowing. The results of some of these are shown in the summary Table *262a*.

262a. Plowing, deep tilling, and subsoiling as influencing the yield of various crops. Summary.

LOCATION	CROP	YEARS	PLOWING	DEEP TILLING	SUBSOILING
Mississippi	[a] Corn	2	30.9 bu.	....	26.3 bu.
Mississippi	[b] Corn	1	32.5 "	30.2 bu.	....
Mississippi	[b] Cotton	1	1225#	1165#	....
Alabama	[c] Corn	—	No benefit		....
Wisconsin	[d] Corn	—	59.02 bu.	56.15 bu.	58.11 bu.
Wisconsin	[d] Oats	—	50.71 "	48.81 "	51.90 "
England	[e] Potatoes	1	100%	....	167%
Missouri	[f] Corn	1	56.4 bu.	....	56.1 bu.
Missouri	[f] Sugar beets	1	6.55T.	....	6.50T.
Missouri	[f] Rutabagas	1	12.22 "	....	11.73 "
Kansas	[g] Corn	1	34.02 bu.	....	33.43 bu.
South Dakota	[h] Winter wheat	1	16.7 "	....	16.3 "
South Dakota	[h] Oats	1	40.6 "	....	39.8 "
South Dakota	[h] Barley	1	18.5 "	....	18.1 "
South Dakota	[h] Flax	1	9.7 "	....	9.4 "
Montana	[i] Corn	9	6190#	....	6439#
Montana	[j] Corn	8	19.1 bu.	....	19.5 bu.
Montana	[k] Corn	12	19.1 "	....	18.2 "
Arizona	[l] Milo	1	468#	....	364#

[a] *Miss. Agr. Expt. Sta. Bul. 170.* 1915; the dynamited plots yielded 28.4 bushels.
[b] *Miss. Agr. Expt. Sta. Bul. 83.* 1904.
[c] *Ala. Agr. Expt. Sta. Bul. 134.* 1905.
[d] *Wis. Agr. Expt. Sta. Bul. 347.* 1922.
[e] *East Anglican Institute of Agr. Rpt.,* Vol. 3, No. 9, p. 479. London.
[f] *Mo. Agr. Expt. Sta. Bul. 32.* 1895.
[g] *Kans. Agr. Expt. Sta. Bul. 64.* 1897.
[h] *U. S. Dept. Agr. Dept. Bul. 1039.* 1922.
[i] *Mont. Agr. Expt. Sta. Bul. 132.* 1919
[j] *Mont. Agr. Expt. Sta. Bul. 140.* 1921.
[k] *Mont. Agr. Expt. Sta. Bul. 194.* 1926.
[l] *Ariz. Agr. Expt. Sta. Bul. 84.* 1918.

Sewell,[24] after an extensive review of literature on the subject, finds that plowing deeper than 7 inches has not generally resulted in an increased crop yield. He suggests, also, that shallow plowing may produce as great yields as deeper plowing, but that the best depth less than 7 inches has not been determined. (269) (270) (278)

TIME OF PLOWING

263. Factors Which Determine Best Time to Plow. Plowing, in most cases, may be done as soon as the previous crop is removed. Claims of large increases in yield due to plowing at a particular time of the year are largely overshadowed by the fact that usually there is neither time nor labor available to do it at such a time. Where labor is available, the yield may determine the time to plow. Too often we judge the yield by the appearance of the crop in its early growth. Observations of fields of corn which start off well in the spring and then fail during hot, dry weather in midsummer are common. Another field, alongside, which started off poorly may come through and make a good yield. The balance between the root system for taking up water and the top growth which gives up water may account for these differences.

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[24] Sewell, M. C.—"Tillage: A Review of the Literature." *Jour. Amer. Soc. Agron.,* Vol. 11, No. 7, p. 287. Oct., 1919.

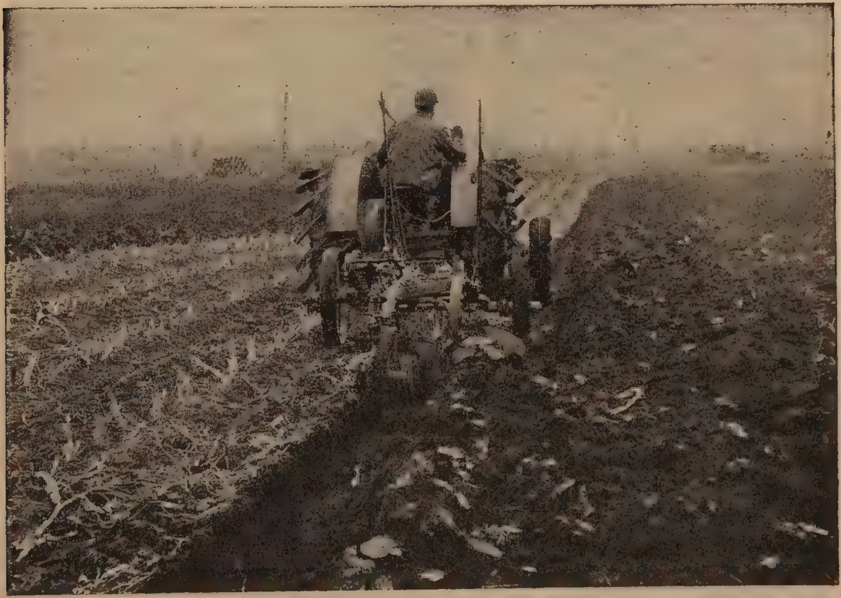

FIG. 63.—Throughout the corn belt corn often follows corn in the rotation. When the crop is harvested late in the fall it is necessary to plow in the spring, but when cut in the fall as for the silo fall plowing is often possible. *Is there any particular advantage in fall plowing? Explain.*

In sections of heavy rainfall in the late fall, winter, or early spring there is danger of erosion if the soil is loosened by plowing in the fall. The surface soil, to the depth of the furrow slice, has in numerous cases been washed away when fall plowed.

Quite often the crop on the land the year previous determines the time of plowing. In the corn belt generally, in 1927, wet weather tended to interfere with spring preparation of the seedbed and corn planting was generally very much delayed. In the case of certain plants, such as biennial clovers and certain weeds, the time of year to plow may be determined by the root character of these plants. It is not recommended in the corn belt generally that we plow sweet clover of the biennial type under in the fall of the year, due to its tendency to volunteer in crops the following year.

In sections of abundant rains the presence of weeds growing on the ground may tend to use the nitrates and thus prevent their loss by leaching. The nitrates become available to following crops by the destruction and decay of the weed growth. This weed factor, which has not been carefully worked out, may be important in certain sections in determining the yields resulting from plowing at different times of the year. Where moisture is a big factor and leaching is not serious, the weed growth can do but very little good.

264. Fall and Spring Plowing. Nebraska reports, as an 8-year average, comparisons of spring and fall plowing for various crops with the crop of the preceding year as shown in Table *264a*.[25]

264a. Comparison of fall and spring plowing on various crops. Nebraska.

CROP GROWN	PREVIOUS CROP	FALL PLOWED	SPRING PLOWED
Corn	Spring wheat	11.9	13.8
Corn	Oats	13.4	13.8
Corn	Corn	18.2	18.5
Barley	Barley	17.1	15.8
Spring wheat	Spring wheat	11.7	12.2
Spring wheat	Oats	11.1	9.6
Spring wheat	Corn	12.0	10.2
Oats	Spring wheat	17.1	19.4
Oats	Oats	20.7	16.3

Moomaw[26] reports the results of fall and spring plowing in North Dakota for a 15-year period with average yields both of small grain crops and of corn in Table *264b*.

264b. Yields of wheat, oats, barley, and corn on spring plowing and on fall plowing in the rotation experiments at the Dickinson substation. North Dakota.

CROP	UNIT OF MEASURE	AVERAGE OF 1908 TO 1923	
		Spring Plowed	Fall Plowed
Wheat	Bushels	16.2	16.5
Oats	"	35.1	33.5
Barley	"	21.2	20.5
Corn			
Grain	"	15.1	15.1
Fodder	Pounds	3,307.0	3,277.0

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[25] Snyder, W. P., and Osborn, W. M.—"Rotations and Tillage Methods in Western Nebraska." *Nebr. Agr. Expt. Sta. Bul. 155.* 1915.

[26] Moomaw, Leroy—"Dickinson Substation Report for 1922 and 1923." *N. Dak. Agr. Expt. Sta. Bul. 189.* 1925.

265. Fall and Spring Plowing Summary. The yield results of a large number of plantings with different crops on fall and on spring plowed land is reported in Table *265a.*

265a. Comparison of spring and fall plowing in different parts of the United States.

STATE	REF. NO.	CROP	YEARS	FALL PLOWED	SPRING PLOWED
North Dakota ...	a	Barley	20 crops	18.9	21.2
North Dakota ...	a	Wheat	" "	16.0	16.2
North Dakota ...	a	Oats	" "	33.0	34.1
South Dakota ...	b	Spring wheat	10	11.60	13.1
Utah	c	Wheat	4	16.8	18.5
Montana	d	Corn	12	20.0	20.8
Montana	e	Winter wheat	2	28.29	28.3
Nebraska	f	Corn	11	20.4	17.3
North Dakota ...	g	Spring wheat	8	16.4	18.2
Nebraska	h	Corn	All tests	20.1	20.5
Great Plains	i	Barley	See ref.	15.0	15.6
Washington	j	Spring wheat	14	24.9	27.8
Montana	k	Corn	8	21.6	21.7
Kansas	l	Oats	8	31.2	31.11
Kansas	m	Corn	3	52.4	51.9
Minnesota	n	Oats	6	63.65	62.03
Minnesota	n	Corn	6	57.92	57.18
Ohio	o	Corn	5	72.2	72.1
Wisconsin	p	Corn	6	58.67	60.68
Wisconsin	p	Oats	9	52.30	53.29
Illinois	q	Corn	6	65.0	65.9

[a] *N. Dak. Agr. Expt. Sta. Bul. 110.* 1915.

[b] *S. Dak. Agr. Expt. Sta. Bul. 201.* 1923.

[c] *U. S. Dept. Agr. Dept. Bul. 157.* 1915.

[d] *Mont. Agr. Expt. Sta. Bul. 194.* 1926.

[e] *Mont. Agr. Expt. Sta. Bul. 87.* 1911.

[f] *Nebr. Agr. Expt. Sta. Bul. 193.* 1923.

[g] *N. Dak. Agr. Expt. Sta. Bul. 141.* 1920.

[h] *Nebr. Agr. Expt. Sta. Bul. 192.* 1923. Spring plow highest 27 times; fall plowing 20 times.

[i] *U. S. Dept. Agr. Farmers' Bul. 968.* 1918. Tests at 14 stations in Great Plains 2 to 8 years at each.

[j] *Wash. Agr. Expt. Sta. Bul. 160.* 1921.

[k] *Mont. Agr. Expt. Sta. Bul. 140.* 1921. Stover yields were higher on fall plowed lands.

[l] *Kans. Agr. Expt. Sta. Bul. 74.* 1897.

[m] *Kans. Agr. Expt. Sta. Bul. 64.* 1897.

[n] *Minn. Agr. Expt. Sta. Bul. 170.* 1917.

[o] *Ohio Agr. Expt. Sta. Bul. 373.* 1923.

[p] *Wis. Agr. Expt. Sta. Bul. 347.* 1922.

[q] *Ill. Agr. Expt. Sta. Bul. 258.* 1925. Second year corn in rotation yielded 1 bu. more on fall plowed land.

In considering the yield results secured from fall and spring plowing comparisons one should have carefully in mind the more important climatic differences represented, and in some cases soil differences. The particular crop represented may also be an important factor. (270) (280)

266. Early and Late Plowing for Winter Wheat. The time of plowing is an important factor under certain soil or climatic conditions, as it may have an appreciable influence on the yield of the crop. Early and late plowing for winter wheat have been compared at several stations. Nebraska[27] reports an 11-year average, where land plowed August 15 yielded 16.2 bushels per acre, while land plowed September 15 yielded 13.7 bushels.

Kansas[28] reports an 8-year test with various methods of seedbed preparation in Table *266a*. This test was carried out on a field planted continuously to winter wheat.

266a. Wheat yields with various times and methods of preparing the seedbed. Kansas.

Preparation	Av. Yield of Wheat, 8 Years
Disked at seeding time	6.8
Plowed Sept. 15, 3 in. deep	12.7
Disked July 15, Plowed Sept. 15, 7 in. deep	17.5
Disked July 15, plowed Aug. 15, 7 in. deep	18.2
Listed July 15, ridges worked down	17.5
Listed July 15, ridges split Aug. 15	17.5
Plowed July 15, 7 in. deep	20.8
Plowed Aug. 15, 7 in. deep, worked immediately	19.5
Plowed Aug. 15, 7 in. deep, not worked until Sept. 15	18.1

Ohio[29] reports the yields shown in Table *266b* from plowing at different times for winter wheat. The yields are average for two years, on Wooster silt loam—a very workable soil. One year a rainfall of one inch the day before plowing, Sept. 15, rendered the late plowing quite satisfactory.

266b. Preparation of the seedbed for wheat. Ohio.

Seedbed Preparation	Wheat Yield, Bushels per Acre
Plowed Aug. 1	35.23
Plowed Aug. 15	32.64
Plowed Sept. 1	29.75
Plowed Sept. 15	30.22
Disked Aug. 1, plowed Sept. 1	30.19
Disked Aug. 1, plowed Sept. 15	31.59
Disked Aug. 1 and 15 and Sept. 15	28.09

Stephens and Hyslop[30] report the average annual acre yields of Turkey wheat after fallow, plowed on different dates at Moro, Oregon, for the years 1914 to 1921 inclusive. The dates of plowing and average annual yields per acre are as follows: Early spring plowing, April 1, 30.0 bushels; medium early spring plowing, May 1, 28.2 bushels; late spring plowing, June 1, 24.6 bushels; early fall (dry), 27.5 bushels; late fall (wet), 26.1 bushels.

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[27] Zook, L. L., and Burr, W. W.—"Sixteen Years' Grain Production at the North Platte Substation." *Nebr. Agr. Expt. Sta. Bul. 193.* 1923.

[28] Sewell, M. C.—"Tillage: A Review of the Literature." *Jour. Amer. Soc. Agron.* Vol. 11, No. 7, pp. 269-290. Oct., 1919.

[29] Williams, C. G.—"Forty-second Annual Report of the Ohio Agr. Expt. Sta." *Ohio Agr. Expt. Sta. Bul. 373*, 1923.

[30] Stephens, D. E., and Hyslop, G. R.—"Wheat Growing after Fallow in Eastern Oregon." *Ore. Agr. Expt. Sta. Bul. 190.* 1922.

Murphy [31] reports the influence of time of plowing on the yield of wheat under Oklahoma conditions; 5-year average in Table *266c*.

266c. Time of plowing for winter wheat; five-year average. Oklahoma.

Date of Plowing	Bushels Per Acre	Tons of Straw
Early—July 15	27.10	1.39
Medium—August 15	24.20	1.19
Late—September 15	22.00	1.15

Helm and Stadler [32] report 4 years' results on the time of plowing as influencing the yield of wheat. At Shelbina, Missouri, land plowed July 15 averaged 15.7 bushels per acre, while that plowed September 15 averaged 10.7 bushels. At Warrensburg, land plowed July 15 yielded 23.6 bushels, while land plowed September 15 yielded 18.6 bushels.

THE EFFECT OF VARIOUS SEEDBED TREATMENTS ON THE NITRATE AND MOISTURE CONTENT OF THE SOIL

267. Time of Plowing for Fallow. Washington. McCall and Wanser [33] report on the nitrate and moisture content at the end of the fallow period as influenced by methods of preparing the fallow in the spring and in the fall in Table *267a*.

267a. Influence of time of plowing for fallow on the moisture and nitrate content of the soil. Washington.

Date of Plowing	Relative Amount of Conserved Moisture	Relative Amount of Accumulated Nitrate-Nitrogen
Dry fall plowing	100	86
Wet fall plowing	108	90
Early spring plowing	126	100
Intermediate spring plowing	125	85
Late spring plowing	103	63

Land plowed in early September before the fall rains started is referred to as "dry fall plowing"; that plowed late in November after the rains as "wet fall plowing." Early spring plowing was usually about March 15 and late spring about June 1.

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[31] Murphy, H. F.—"Cultural Methods for Corn and Grain Sorghums on Oklahoma Soils." *Okla. Agr. Expt. Sta. Bul. 150.* 1925.

[32] Helm, C. A., and Stadler, L. J.—"Productive Methods for Wheat in Missouri." *Mo. Agr. Expt. Sta. Bul. 188.* 1921.

[33] McCall, M. A., and Wanser, H. M.—"The Principles of Summer-Fallow Tillage." *Wash. Agr. Expt. Sta. Bul. 183.* 1924.

In the spring the plats were plowed 4, 6, and 8 inches deep at each date, and the moisture and nitrate content at the end of the fallow period determined. When the surface soil contained a relatively high moisture content, the deeper plowing was most efficient in moisture conservation; but when the surface soil was less moist, the deeper plowing was at a disadvantage. From the moisture conservation standpoint the drier the average condition the shallower the plowing should be. With reference to nitrate accumulation at the end of the fallow period the authors consider that there is no consistent advantage for any particular depth of plowing at any date.

Harvest disking before plowing for fallow was an advantage from the moisture conservation standpoint only when the fallow was plowed early in the fall. For other times of plowing the harvest disking was actually detrimental to the absorption of moisture. They find that where spring plowing is to be delayed to any extent, early spring disking will conserve moisture and accumulate nitrates in a fallow better than plowing without the previous disking. Cultivation immediately after plowing had no advantages over delayed cultivation. Subsurface packing after plowing had no advantage from the standpoint of moisture conservation, but there was a slight, rather consistent advantage, in nitrate conservation. From the standpoint of moisture conservation they conclude that disking may be substituted for plowing in preparing the land for fallow with equal results. Plowing evidently has an advantage from the standpoint of nitrate accumulation however. They find a significant positive correlation between soil moisture, accumulated nitrate nitrogen, and yield of grain and straw. The correlation between grain yield and soil moisture is more significant than that between grain yield and nitrate nitrogen. When moisture is markedly deficient, an excessive early growth, due to large supplies of nitrate, may reduce the ultimate yield of grain. A proper balance between these two is necessary. The quality of the grain is correlated closely with the amount of accumulated nitrate nitrogen in the soil.

267b. Time to plow for fallow. Montana.

TIME OF PLOWING	YIELDS OF CROP	
	Winter Wheat	Spring Wheat
1 year previous, fall plow, worked at once	28.2	16.8
1 year previous, fall plow, left rough	31.4	18.8
5 months previous, spring plow	24.3	18.4
3 months previous, spring plow	23.5	16.3

Montana[34] has obtained the results given in Table *267b* from plowing at different times for fallow as an average for 6 years.

268. Disking *vs.* Plowing. Washington. McCall and Wanser[35] also report, in Table *268a,* the relative moisture content and nitrate accumulation secured at the Washington Station as a result of disking at different times in comparison with plowing only.

268a. Seedbed preparation as influencing soil moisture and nitrates. Washington.

TREATMENT	RELATIVE AMOUNTS OF MOISTURE CONSERVED—PER CENT	NITRATES ACCUMULATED—PER CENT
Disked in fall, again early in spring, again intermediate in spring, no plowing	99	88
Early spring disked, intermediate spring disked, no plowing	106	83
Early spring disked, alternate early spring plowed	99	87
Early spring plowed	100	100

269. Depth of Plowing and Moisture. The actual moisture content of the soil when treated in various ways has been studied at the Utah Station.[36] The moisture content was determined when the seedbed was stirred to different depths by plowing and subsoiling. The moisture content was determined to a depth of 6 feet and the results are given in Table *269a.*

269a. Effect of subsoiling and deep plowing on the moisture held in the soil; four-year average. Utah.

	PER CENT MOISTURE AT DATE			TOTAL YEARLY AVERAGE	YIELD OF WHEAT
	April	June	Sept.		
Subsoiled 18 in. deep.........	18.49	17.96	17.07	17.84	16.0
Subsoiled 15 in. deep.........	19.41	17.95	17.92	18.43	16.7
Plowed 10 in. deep...........	19.22	18.11	17.66	18.33	17.5
Plowed 5 in. deep...........	18.90	17.82	18.06	18.26	17.2

Nebraska reports[37] moisture tests made on 3 dates each year on land plowed 3 inches, 7 inches, and 14 inches deep and cropped to wheat. The yield for the 3-inch plowing was 13.2 bushels as an 8-year

[34] Seamans, A. E.—"Fallow Experiments in South Central Montana." *Mont. Agr. Expt. Sta. Bul. 142,* p. 23, 1921.

[35] McCall, M. A., and Wanser, H. M.—"The Principles of Summer-Fallow Tillage." *Wash. Agr. Expt. Sta. Bul. 183.* 1924.

[36] Cardon, P. V.—"Tillage and Rotation Experiments at Nephi, Utah." *U. S. Dept. Agr. Dept. Bul. 157.* 1915.

[37] Zook, L. L.—"Winter Wheat Seedbed Preparation." *Nebr. Agr. Expt. Sta. Bul. 178.* 1921.

average; 7-inch plowing, 15.2, and 14-inch plowing, 14.5. With reference to moisture they conclude: "In no instance in these tests, covering a four-year period, has there been an appreciable difference in the rapidity of moisture storage, in the amount of moisture stored, or in the manner or completeness of its exhaustion, whether the plowing has been 3, 7, or 14 inches in depth."

For 2 years, 1919 and 1920, moisture tests were made on plots at the Illinois Station [38] comparing the effect of depth of plowing. The yields on these plots are given in Table *261c* and the moisture content in Table *269b*. Fourteen samples were taken from the surface and subsurface on each plot.

269b. Moisture in the soil after ordinary plowing compared with subsoiling and dynamiting. Illinois.

DEPTH	PLOWED 7" DEEP PER CENT	SUBSOILED PER CENT	DEEP TILLED PER CENT	DYNAMITED PER CENT
Seasonal average, surface 0 to 8 in.	28.5	28.4	26.1	29.3
Seasonal average, subsurface 8 in. to 20 in.	24.9	23.9	24.0	24.9

Sewell and McCall [39] report from Kansas that early summer tillage increases the amount of soil moisture and nitrates in comparison with late summer tillage for wheat.

They find also that the depth of plowing does not influence the soil moisture content. Seven-inch plowing showed an increase in nitrate accumulation over 3-inch plowing. Plowing in July resulted in greater nitrification and higher yields than were obtained when the weeds were controlled by scraping the surface without plowing.

270. Spring *vs.* Fall Plowing as Influencing Soil Moisture. The Utah Station [40] reports moisture determinations in each foot of soil to a depth of 6 feet, on spring plowing, and on fall plowing. Table *270a* gives an average of 4 years for moisture determinations made in the spring, summer, and fall of each year.

This test was made on a very deep alluvial soil varying in texture from clay to a sandy loam. The soil is classed as heavy and is hard to work as it becomes very sticky when wet and very hard when dry. The average rainfall was 13.4 inches per year.

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[38] Smith, Raymond S.—"Experiments with Subsoiling, Deep Tilling, and Subsoil Dynamiting." *Ill. Agr. Expt. Sta. Bul. 258.* 1925.

[39] Sewell, M. C., and Call, L. E.—"Tillage Investigations Relating to Wheat Production." *Kans. Agr. Expt. Sta. Tech. Bul. 18*, p. 48. 1925.

[40] Cardon, P. V.—"Tillage and Rotation Experiments at Nephi, Utah." *U. S. Dept. Agr. Dept. Bul. 157.* 1915.

270a. Utah results on the moisture in spring and in fall plowing.

DEPTH OF SAMPLE	SPRING PLOWING			FALL PLOWING		
	April	June	Sept.	April	June	Sept.
1st foot, per cent moisture ...	19.33	14.57	13.65	21.22	15.71	14.01
2nd foot, " " "	20.96	19.38	18.74	21.21	19.58	18.02
3rd foot, " " "	20.87	19.07	18.64	19.94	18.40	18.11
4th foot, " " "	20.76	18.96	18.17	16.91	17.02	16.98
5th foot, " " "	19.80	19.08	17.28	16.15	16.13	15.54
6th foot, " " "	18.54	18.46	17.24	18.00	18.82	16.50
Average per cent moisture for each test	20.04	18.25	17.29	18.90	17.61	16.53
Average per cent moisture for year		18.53			17.68	
Yield of wheat		18.5 bu.			16.8 bu.	

Cardon reports from the average results of 5 years that spring plowing was better than fall plowing from the standpoint of moisture conservation, yield of grain, and the cost of producing the crop. His results also show that there was no advantage in deep plowing or subsoiling over shallow plowing as far as moisture conservation was concerned. One year's results were given comparing deep fall plowing and shallow spring plowing with no difference in soil moisture and only a slight difference in yield.

Montana[41] reports moisture tests on spring and fall plowing for a 3-year trial,—1908-1910,—in Table *270b.*

270b. Time of plowing and soil moisture content; three-year average. Montana.

	PER CENT MOISTURE AT DIFFERENT DEPTHS					
	First Foot	Second Foot	Third Foot	Fourth Foot	Fifth Foot	Average
Spring plow	16.3	14.6	12.5	11.4	11.1	13.2
Fall plow	16.2	13.8	11.2	10.1	10.5	12.4

COMPACTING THE SEEDBED

271. Packing the Seedbed for Wheat. Nebraska[42] gives the effect of packing the seedbed for wheat. As an 8-year average, the packed seedbed yielded 15.4 bushels per acre, while that not packed yielded 13.6 bushels. The first 3 years the packing was done with an ordinary disk set straight and weighted. The last 5 years a Campbell

[41] Atkinson, Alfred, *et al.*—"Dry Farm Moisture Studies." *Mont. Agr. Expt. Sta. Bul. 87.* 1911.

[42] Zook, L. L., and Burr, W. W.—"Sixteen Years' Grain Production at the North Platte Substation." *Nebr. Agr. Expt. Sta. Bul. 193.* 1923.

subsurface packer was used. In all cases, packing was done soon after plowing.

Missouri[43] reports methods of preparing a seedbed for winter wheat after soybeans (3 years). When the seedbed was double disked and rolled, the yield was 23.3 bushels, while double disking and harrowing yielded 20.9 bushels and double disking only yielded 20.2 bushels.

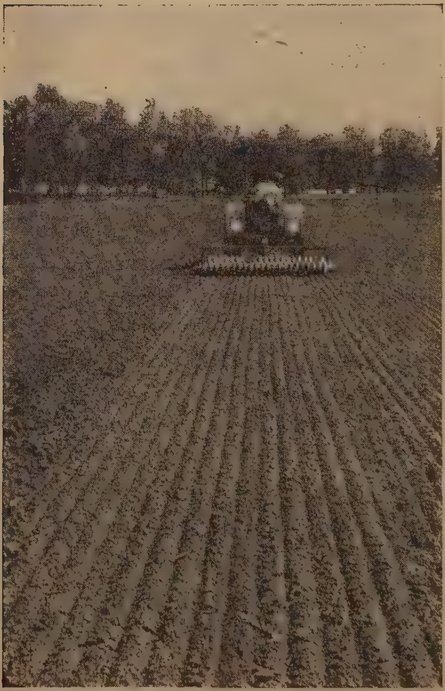

FIG. 64.—Many different types of machines have been perfected for pulverizing and firming the seedbed. The cultipacker is one of the best of these implements. *For what crops and under what conditions is a well compacted, firm seedbed particularly important? Why?*

Fairfield[44] reports the result of the packer on both fall and spring plowing in Alberta, Canada. The yield of wheat as a 2-year average was decreased 1.12 bushels on fall plowing and was not affected on spring plowing by packing.

Oregon[45] reports the results of seedbed packing on wheat yields in Table *271a,* and the effect on moisture in the soil in Table *271b,* on the facing page.

SUMMER FALLOW

272. Summer Fallow. Summer tillage or the fallow system is used in the dry-land farming sections. In this system the land is planted one season and then allowed to lie bare or cultivated without a crop for one season.

Fallowing, in order to pay out, must yield almost as much in 1 year as the regular methods of preparation do in 2. Results are reported from a number of sources comparing yields secured from summer fallow with those following cultivated crops. The yield comparison of the different crops is of interest.

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[43] Helm, C. A., and Stadler, L. J.—"Productive Methods for Wheat in Missouri." *Mo. Agr. Expt. Sta. Bul. 188.* 1921.

[44] Fairfield, W. H.—"Cultural Experiments on Dry Land." *Canada Expt. Farms. Lethbridge (Alta.) Rpt. Supt. 1925*, p. 21.

[45] Stephens, D. E., and Hyslop, G. R.—"Wheat Growing after Fallow in Eastern Oregon." *Ore. Agr. Expt. Sta. Bul. 190.* 1922.

271a. Average acre yields of Turkey winter wheat grown after summer fallow plowed April 1, May 1, and June 1. Oregon.

Time of Plowing and Cultivation of Fallow	Not Packed Bushels	Subsurface Packed Bushels	Surface Packed Bushels
April 1, clean fallow	31.7	31.1	32.2
April 1, one harrowing	27.2	28.5	...
May 1, clean fallow	27.7	28.4	28.6
May 1, one harrowing	26.2	25.9	...
June 1, clean fallow	22.9	21.7	22.4
June 1, one harrowing	22.6	22.5	...
Average	26.4	26.3	...

271b. Percentage of moisture in the first foot and total six feet of soil at beginning and end of fallow season, packed with subsurface packer and not packed, years 1919-1921, inclusive. Oregon.

Year	April 1				Sept. 4			
	Packed First Foot	Not Packed First Foot	Packed Total 6 Feet	Not Packed Total 6 Feet	Packed First Foot	Not Packed First Foot	Packed Total 6 Feet	Not Packed Total 6 Feet
Average (%)	13.3	14.4	11.6	11.8	10.4	10.2	11.2	11.3

North Dakota[46] reports yields at the substations and at the central station comparing summer tillage (fallow) with continuous cropping for various crops in Table *272a*.

272a. Summer tillage compared with continuous cropping. North Dakota.

Station	System	Wheat	Oats	Barley	Corn
8 years at Edgely	Cont. cropping	13.2	26.8	17.0	3,610
	Summer tillage	14.8	42.5	20.0	3,400
6 years at Dickinson	Cont. cropping	15.6	30.8	25.5	3,750
	Summer tillage	27.8	51.1	32.5	2,880
5 years at Williston	Cont. cropping	14.2	29.5	16.1	6,890
	Summer tillage	19.8	46.0	28.8	7,370
3 years at Hettinger	Cont. cropping	11.2	34.8	23.7	5,840
	Summer tillage	21.5	48.6	31.8	5,540
All stations	Cont. cropping	13.6	30.5	20.6	5,238
	Summer tillage	21.0	47.1	28.3	5,479

273. Summer Fallow *vs.* Cropping with Corn. Trials are reported from a number of stations comparing the yields secured following corn with those secured from summer fallow in Table *273a*.

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[46] Thysell, John C., *et al.*—"Dry Farming Investigations in Western North Dakota." *N. Dak. Agr. Expt. Sta. Bul. 110.* 1915.

273a. Comparison of crops after corn and after fallow. Summary.

STATE	REF.	CROP	YEARS	YIELD AFTER FALLOW	YIELD AFTER CORN
North Dakota ...	[a]	Wheat	See ref.	21.5 bu.	18.4 bu.
North Dakota ...	[a]	Oats	" "	41.0	37.7
North Dakota ...	[a]	Barley	" "	28.3	25.8
Utah	[b]	Wheat	5	12.9	15.5
Nebraska	[c]	Wheat	5	26.0	18.7
Nebraska	[d]	Spring wheat	10	16.8	11.7
Nebraska	[d]	Winter wheat	10	20.2	14.1
Nebraska	[d]	Oats	10	31.5	25.8
Nebraska	[d]	Barley	10	26.9	15.1
Montana	[e]	Winter wheat	7	26.2	19.6
Montana	[e]	Spring wheat	8	20.0	15.7
Montana	[e]	Oats	8	47.4	35.5
Montana	[e]	Barley	8	24.8	23.1

[a] *N. Dak. Agr. Expt. Sta. Bul. 110.* 1915. Av. of four stations (4 to 8 years at each).
[b] *U. S. Dept. Agr. Dept. Bul. 157.* 1915. [d] *Nebr. Agr. Expt. Sta. Bul. 192.* 1923.
[c] *Nebr. Agr. Expt. Sta. Bul. 193.* 1923. [e] *Mont. Agr. Expt. Sta. Bul. 142.* 1921.

274. Depth of Plowing Summer Fallow. The effect of different depths of plowing for fallow has been reported by McKillican.[47] The plowing was done in midsummer and the wheat sown the following spring. After the wheat was harvested, the land was plowed according to the depth specified and the land seeded to oats the next year. The work was continued over a period of 11 years with the results given in Table *274a.*

274a. Eleven-year average yield of wheat and oats on fallow plowed to various depths. Manitoba (Can.).

PLOT NO.	DEPTH OF PLOWING	YIELD OF WHEAT 11-YEAR AVERAGE	YIELD OF OATS THE FOLLOWING SEASON 11-YEAR AVERAGE
1	Plowing 3 in. deep	40	72
2	Plowing 4 in. deep	40	74
3	Plowing 5 in. deep	41	73
4	Plowing 6 in. deep	40	73
5	Plowing 7 in. deep	39	73
6	Plowing 8 in. deep	41	74
7	Plowing 5 in. deep subsoil 4 in.	39	75
8	Plowing 6 in. deep subsoil 4 in.	39	75
9	Plowing 7 in. deep subsoil 4 in.	39	75
10	Plowing 8 in. deep subsoil 4 in.	38	76

Tinline[48] measured the influence of the first and second crops from the different depths of plowing summer fallow.

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[47] McKillican, W. C.—"Cultural Experiments." *Canada Expt. Farms. Brandon (Man.) Farm Rpt. Supt.*, p. 18. 1923.

[48] Tinline, M. J.—"Cultural Experiments." *Canada Expt. Farms. Scott (Sask.) Farm Rpt. Supt.*, p. 35. 1922.

Plowing has been done in early June to depths of 3, 4, 5, 6, 7, and 8 inches for wheat and for oats. The average 8 years' results show nearly identical yields of wheat throughout. The yield of the 8-inch plowing was about 2 bushels lower than the 4-inch plowing. Oats, likewise, yielded highest with 4-inch plowing and about 5 bushels less where it was plowed 8 inches deep.

STUDY QUESTIONS ON CHAPTER IX

1. What are the more important factors which affect the draft of plows and how do these operate?
2. How do you account for the decrease in yield which resulted from plowing 12 inches for corn, as reported in the Pennsylvania experiments?
3. What effect would deep plowing have on the moisture content of the soil if this were done after the period of most abundant rains? Before the period of abundant rains? What effect would deep plowing have on root development? On plant food?
4. On what theory was subsoiling advocated? Under what conditions would you advise it?
5. How do you account for the comparative yields secured from plowing, subsoiling, and deep tilling?
6. What factors determine the best time to plow? What time of year do you advise plowing for each of the major crops grown in your section. Why?
7. Under what conditions would you expect early plowing to be better than late plowing for winter wheat?
8. How do you account for the differences in yield reported from the Oregon Station, from early, medium, and late plowing for wheat?
9. What effect does plowing have on the moisture content of the soil? Why? On the nitrate content? In general, what would be the effect of packing a seed-bed on the yield? On the moisture content? On the entrance of water into the soil?
10. Under what conditions is the summer fallow advisable? Why?

Application assignments on this chapter are included with those following Chapter X.

CHAPTER X

THE SEEDBED

Tillage is the most expensive item in the production of most of our crops and the necessity of lowering the cost of producing crops has focused attention on this subject. Any method of production by which the labor of preparing the seedbed or of cultivation can be reduced without decreasing the yield proportionately is of vital importance.

The Tilth of Soils

275. Soil Tilth. Most people who have had experience in producing crops appreciate the desirability of having soil in "good tilth"; yet it is sometimes rather difficult to describe or define the term in spite of its more or less general use. Many factors are important in influencing the tilth of soils while tilth, in turn, as the combined result of these factors, plays an important part in the practical production of crops.

A soil with a fine crumb structure is said to be in good tilth. The heavier soils are the more difficult ones to get into a state of good tilth. At one time it was the common practice to burn clay soils as this lessened their tendency to bake into hard masses, a condition caused by the destruction of the colloid material of the soil. It is now a well recognized fact that the liming of these soils often has a marked influence in improving their physical structure, *i.e.* their tilth.

276. Tilth and Plant Growth. Bornemann,[1] in Germany, reported the influence of soil tilth on plant growth and yield. The yield of wheat increased with the fineness of the crumb structure of soils. Germination occurred earlier in more loosely stratified soils. The density of stratification had no effect on yield where the crumb structure was uniform. Loose soils produced plants with longer leaves than did dense soils. The finer the crumb structure and the more loosely it was stratified the greater was the water capacity. The moisture capacity was greater with an impervious subsoil and when the moisture was added in the form of rain.

Scarified soils were superior from the standpoint of heat retention and bacterial activity. Where loam and clays were pulverized in a dry condition they did not readily resume their firm shape and scarified clay soils were completely changed in character. Wheat plants suffered less injury from freezing in scarified soils than in ordinary plowed fields. Scarifying the soil pulverized thoroughly the top layer of soil.

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[1] Bornemann, —.—"Soil Physics Studies with Reference to Cultivation by Scarification." *Deut. Landw. Presse*, Vol. 49, Nos. 47, 50, and 51. 1922. Abstracted in *E. S. R.* Vol. 49, pp. 210-211. 1923.

277. Tilled and Milled Soils. Patitz[2] reports a test using a rotary tiller in the preparation of the seedbed for potatoes near Berlin, Germany. The yield of the plots which were treated with the rotary tiller was 438 bushels per acre in comparison with 393 bushels for the plowed land. The rotary tiller is equipped with a cylinder somewhat like the cylinder of a thresher, which revolves rapidly, tearing the soil loose and pulverizing it thoroughly to a depth of 6 or 8 inches, and then throwing it back against a shield from which it falls to the surface.

Patitz reports tiller tests in Hungary by Professor Raszo which indicated an average increase of 21 per cent from the use of the rotary tiller in preparing seedbeds for wheat, rye, oats, corn, and sugar beets.

Dr. Ruth[3] compared yields obtained by plowing at different depths and at different times with yields obtained by pulverizing a soil thoroughly, using the Mayenburg soil tiller. The thoroughly pulverized soil is called milled soil. Milling the soil to a depth of 8 inches increased the yield of potatoes approximately 11 per cent per cwt. over potatoes on soil fall plowed to a depth of 12 inches, or spring plowed to a depth of either 8 or 10 inches.

278. Tillage and Aëration. Russell and Appleyard[4] made a study of soil air on the plots at Rothamsted, England. They found that the free air of the soil to a depth of 6 inches was very similar in composition to atmospheric air, but that it had more carbon dioxide and less oxygen and showed a wider fluctuation in composition than the atmospheric air. The air dissolved in the water of the soil consists mainly of carbon dioxide and nitrogen and has practically no oxygen. Growing crops could not be shown to produce a marked increase in the carbon dioxide of the soil air.

Romell[5] after a study of aëration in soils of Sweden estimates that approximately 7 liters of carbon dioxide are being given off each day by a square meter of soil, and that it would be necessary for the soil to be completely aërated once each hour to a depth of 20 centimeters in order to prevent the accumulation of the carbon dioxide in excessive amounts. After a study of all the factors which might bring about complete aëration, he concludes that diffusion is most largely responsible. He also thinks that, as a rule, aëration is generally sufficient in ordinary soils. He does not believe that earthworms have very much to do with bringing about good aëration of the soil nor in providing a crumbly structure. He finds that aëration usually is defective in damp soils and is likely to be deficient in clay.

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[2] Patitz, Max—"The Rotary Tiller or Soil Milling Machine." *Amer. Soc. Agr. Engin. Trans.* Vol. 8, p. 68. 1914.

[3] Ruth, —.—"My Experiences with Green Manuring" (trans. title), Mitteilungen der Deutschen Landwirtschafts-Gesellschaft. May, 1914. Cited by Patitz, Max in *Amer. Soc. Agr. Engin. Trans.* Vol. 8, p. 68. 1914.

[4] Russell, Edward John, and Appleyard, Alfred—"The Atmosphere of the Soil: Its Composition and the Causes of Variation." *Jour. Agr. Sci.*, Vol. 7, pp. 1-48. 1915.

[5] Romell, Lars Gunnar—"Soil Aeration." *Internat'l Rev. Sci. and Pract. Agr.* (Rome) n.s. Vol. 1, pp. 281-297. 1923.

Wollney [6] believed that the most important rule for tillage was to increase the amount of atmospheric air in the soil as much as possible. He found that soils in the powdery condition contained less air than those in a crumbly condition. The difference increased with increasing water content. He found also that soils of fields in the crumbly condition were more permeable to air than powdery ones.

Leather [7] studied diffusion of gases in the soil and concluded that the rate of diffusion of air through soils to a depth of 12 to 15 inches is sufficient to warrant the statement that cultivation is unnecessary for purposes of aëration. His investigations show that even during the wettest weather the volume of gas falls to only 15 or 20 per cent of the total soil volume, or about one-half that which is present during long periods of dry, hot weather. **(168-170)**

279. Aëration and Plant Growth. Day [8] grew wheat, oats, barley, and peas in jars, one set of which was aërated daily during the growing season by drawing air through the jar in sufficient amounts to completely change the air. There was no marked difference in the growth of the plants except peas. In the aërated jars the peas germinated 81 per cent; in unaërated ones, 61 per cent. The growth in the aërated jars was nearly twice as great as that in the unaërated jars. In another series alfalfa and soybeans were included. Oats and peas yielded slightly better in the aërated jars; alfalfa and soybeans did not mature, but the beneficial effect from the aërated jars was very noticeable.

Knight [9] reports that maize grown in aërated soil cultures produced a greater weight of dry matter than control plants in non-aërated soils. The concentration of CO_2 in the nonaërated series was markedly higher than in the controls. The normal aëration was prevented by sealing the container over the top. (192)

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[6] Wollney, E.—*Die Durchlüftung der Akerererde Fuhlings Landw. Zeit.* Vol. 48, pp. 377-402. 1889.

[7] Leather, J. Walter—"Records of Drainage in India." *India Dept. Agr. Mem. Chem. Ser.* Vol. 2, pp. 85-140, 1915.

[8] Day, D. E.—"Experiments in Aeration." *Ontario Agr. Col. Ann. Rpt. 31*, p. 37. 1906.

[9] Knight, R. C.—"The Response of Plants in Soil and Water Culture to Aerations of the Roots." *Brit. Ass'n Adv. Sci. Rpt. 91*, p. 495. 1923.

280. Time of Plowing and Tilth. When a soil in good physical condition with the proper crumb structure is saturated and then pressure is applied such as would come from plowing while wet or by trampling by stock, soil particles move freely by each other, due to the water, and the crumb structure is destroyed. Such a soil is said to be "puddled." Alternate freezing and thawing of soil with a normal amount of moisture aids in building up the tilth or crumb structure, but if there is an excess of water present, freezing and thawing will tend to break down the granules and instead of producing good tilth a puddled condition will result. The alternate freezing and thawing of wet soils results in "heaving" with serious injury if such crops as alfalfa or winter wheat are occupying the soil. Proper drainage, so that soils will retain a medium to fine grain, will prevent very largely the tendency to heave.

Walster,[10] in an effort to determine the influence of fall and spring plowing on the tilth of soil, determined the per cent of clods and of crumb structure having a certain diameter in both spring and fall plowing.

280a. Fall and spring plowing as influencing the tilth of soils. North Dakota.

	FALL PLOWED PER CENT	SPRING PLOWED PER CENT
Clods larger than .25 inch in diameter	0.0	55.8
Clods ranging from .25 inch to .131 inch in diameter	12.6	16.0
Crumbs .131 in. to .055 in diameter	15.7	12.2
Crumbs .065 in. in diameter and smaller	71.7	16.0

SEEDBED PREPARATION FOR SPECIFIC CROPS

281. Interpreting Yield Comparisons. Before presenting actual data comparing various methods of culture and preparation of the seedbed it should be understood that slight differences do not prove one method better than another. Attempts to get identical results with the same methods on adjoining and alternating plots resulted in unaccountable variations as high as 1½ bushels per acre at the New York Station. From an experiment conducted properly and continued over a long enough period it is possible to get a general idea of what to expect, but it would still be impossible to say definitely what will happen under other environmental and soil conditions. As has already been stated, the data presented here is not selected to prove a certain theory or to uphold a certain viewpoint. A search of the literature has been made and the data on the different subjects grouped for the convenience of the reader in order that he may be able to reach justified conclusions on the various topics.

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[10] Walster, H. L.—"Fall Plowing *vs.* Spring Plowing for North Dakota Grain Crops." *N. Dak. Agr. Expt. Sta. Bul. 141.* 1920.

282. The Seedbed for Corn. Much that has been included in preceding chapters applied directly to the preparation of the seedbed for corn and this is also true for the other crops which are discussed in following sections. However, there are certain studies on the seedbed which apply especially to the corn crop and which are reported here.

FIG. 65.—A familiar scene throughout the corn belt during late April and early May. *What is an ideal seedbed for corn and in what way, if any, does this differ from the ideal seedbed for winter wheat? For cotton? For sorghum?*

The Illinois Station[11] reported in 1893[12] that when a gray silt loam with a tight subsoil was not plowed and weeds were controlled with a hoe, corn yielded 6.0 bushels as a 5-year average; where plowed and weeds controlled by hoeing, the yield was 18.9 bushels per acre. Corn grown on a brown silt loam, which was not plowed, yielded 31.4 bushels per acre as an average for 8 years, while plowed land produced 45.9 bushels.

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[11] Mosier, J. G., and Gustafson, A. F.—"Soil Moisture and Tillage for Corn." *Ill. Agr. Exp. Sta. Bul. 181*, pp. 570 and 582. 1915.

[12] Morrow, G. E., and Gardner, F. D.—"Field Experiments with Corn in 1891." *Ill. Agr. Expt. Sta. Bul. No. 20*, pp. 49-72. 1892.

The same report gives composite yields of corn grown on land plowed to different depths and on land not plowed at all. The soil was loose and porous to a considerable depth and had great capillary capacity. The land had not been plowed the 2 years preceding the year in which the experiment was made. After the seedbed preparation, as indicated in Table *282a,* all plowed plots were worked down with a harrow and the corn planted. No cultivation was given in this Illinois experiment except that the weeds were kept down by scraping with a hoe.

282a. Yield of corn on land plowed to different depths or disked only.

TREATMENT 1889 TO 1892	CORN YIELD BU. PER ACRE	TREATMENT 1890	CORN YIELD BU. PER ACRE
Not plowed, disked shallow ...	56.4	Plowed 2 in. deep	54.0
Plowed 2 in. deep	59.6	Plowed 5 in. deep	57.5
Plowed 4 in. deep	69.4	Plowed 10 in. deep	56.0
Plowed 6 in. deep	69.3		
Plowed 8 in. deep	71.1		

Seedbed preparation for corn was studied for a period of 7 years by Clark,[13] 1916 to 1922, at the Charlottetown Station, Canada. Corn was planted after potatoes in a rotation of hoed crop, grain, and clover. The 7-year average yields are shown in Table *282b.*

282b. Seedbed preparation for corn following potatoes. Canada.

PLOT	SEEDBED PREPARATION	SEVEN-YEAR AVERAGE YIELD OF CORN PER ACRE BUSHELS
1	Seed, smoothing harrow	45.0
2	Disk, seed, smoothing harrow	49.1
3	Disk, smoothing harrow, seed, smoothing harrow	50.9
4	Double disk, smoothing harrow, seed, smoothing harrow	50.5
5	Smoothing harrow early as possible, double disk, smoothing harrow, seed, smoothing harrow	45.0
6	Double disk, smoothing harrow, seed, smoothing harrow	54.2
7	Double disk, smoothing harrow, seed, smoothing harrow, roll when grain is 4 or 5 in. high	48.0
8	Spring harrow, then double angle spring harrow, smoothing harrow, roll, seed, smoothing harrow ...	53.6
9	Double disk, smoothing harrow, seed, roll, smoothing harrow	51.1
10	Double disk, smoothing harrow, roll, seed, smoothing harrow	37.5

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[13] Clark, J. A.—"Cost of Production of Field Crops." *Canada Expt. Farms Charlottetown (P. E. I.) Sta. Rpt. Supt.* 1922.

The 20-year average precipitation at this station is 38.55 inches annually.

Seamans,[14] reporting work carried through 11 years in Montana comparing various methods of seedbed preparation for continuous corn culture under dry-land conditions, states that spring plowing yielded 19.1 bushels of grain per acre and 1,613 pounds of stover; fall plowing, 17.8 bushels and 1,792 pounds of stover; subsoiling, 18.2 bushels and 2,040 pounds of stover; listing, 26.6 bushels of grain and 1,539 pounds of stover, and fallow, 30.6 bushels of grain and 2,495 pounds of stover.

283. Listing or Plowing for Corn. The lister is used in the semiarid Great Plains area and in the South. In the drier sections a combination lister-planter is used which prepares the ground and plants at the same time. In the South planting is often done on double listed ground. The ground is first ridged with the lister, then the lister is used a second time to "bust" the ridge. The lister is quite commonly called a "middle-buster" in the South. The rows may be in the lister furrow or planted on the ridge after it has been dragged down somewhat.

Marysville, in Nodaway County, Missouri, reports [15] a comparison of various methods of seedbed preparation for corn. Nine-year averages are given in Table *283a*.

283a. Methods of seedbed preparation for corn; average of nine years. Missouri.

METHODS OF SEEDBED PREPARATION	BUSHELS PER ACRE	AV. INCREASE OVER SURFACE PLANTING
Ground plowed, crop surface planted	51.6	0.0
Ground plowed, crop planted in shallow furrows	59.0	7.4
Land double listed	57.6	6.0
Land double disked, single listed	60.2	8.6
No disking, land single listed	64.2	12.6

At Warrensburg, Missouri,[16] surface planting without furrow openers yielded 28.4 bushels, while the same method of planting with furrow openers yielded 32.3 bushels for the 4 years, 1917 to 1920, inclusive.

Nebraska reports,[17] as a 14-year average, that listing for corn produced 21.3 bushels, while plowing and surface planting yielded 17.7 bushels.

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[14] Seamans, A. E.—"Experiments with Corn on Dry Land at the Huntley Branch Station." *Mont. Agr. Expt. Sta. Bul. 194.* 1926.

[15] Helm, C. A.—"Corn in Missouri." *Mo. Agr. Expt. Sta. Bul. 185.* 1921.

[16] Helm, C. A.—"Corn in Missouri." *Mo. Agr. Expt. Sta. Bul. 185.* 1921.

[17] Zook, L. L., and Burr, W. W.—"Sixteen Years' Grain Production at the North Platte Substation." *Nebr. Agr. Expt. Sta. Bul. 193.* 1923.

Illinois reports[18] 1 year's results in which 10 listed plots averaged 51.1 bushels, while ordinary plowed and surface planted plots averaged 55.9 bushels of corn per acre.

Salmon reports[19] 10 years' comparisons of different methods of planting corn in Kansas. Listed corn yielded 47.1 bushels of grain; surface planting, 46.8, and corn planted with furrow openers, 48.2. The furrow planting is a modification of surface planting. The seedbed is prepared in the ordinary way and the shallow furrows opened by means of disks which are attached to the shoes of the corn planter.

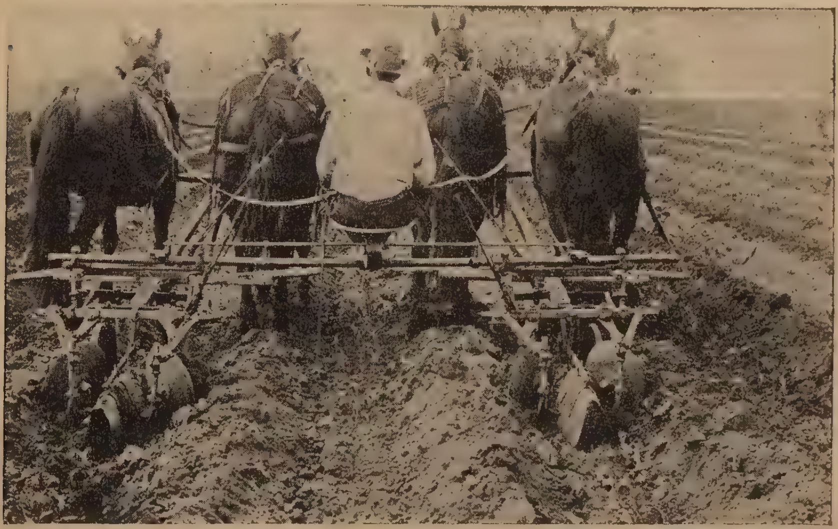

FIG. 66.—In a field of listed corn. *Under what conditions is listing preferable to plowing in the preparation of the seedbed for the corn crop?*

Salmon states that listing as a method of planting corn is adapted to regions having limited rainfall and light types of soil; listed corn can be planted and cultivated more readily and cheaply than surface planted corn, and it is more drouth-resistant.

The surface-planting method is best for regions having abundant precipitation and heavy types of soil. Surface-planted corn is not as susceptible to damage from heavy rains as is listed corn, makes a quicker and more abundant growth, and, under favorable conditions, often has a greater capacity for production. **(258-268.)**

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[18] Gardner, F. D.—"Corn Experiments, 1894." *Ill. Agr. Expt. Sta. Bul. 37.* 1895.

[19] Salmon, S. C.—"Corn Production in Kansas." *Kans. Agr. Expt. Sta. Bul. 238.* 1926.

284. Stunting Corn to Increase the Yield. Hutchinson [20] reports from the South Carolina Station that many farmers in that state attempt to increase the yield of corn by stunting the plants while they are young so as to produce a small stalk, later applying fertilizers and giving good tillage, expecting in this way to produce the maximum yield of grain. By this practice it is easily possible to reduce the height of stalk from one-fourth to one-third. It appears to be easier for the average grower to lessen the yield in this way than to increase it. The judgment of the grower must determine just when harsh treatment must stop and good treatment begin. That it is sometimes possible to increase the yield by such treatment is indicated from work carried out at the Peedee (S. C.) Station. In this trial corn that was stunted by withholding fertilizers until after the time of planting yielded 48 bushels, while corn land handled similarly but fertilized before planting and also during the growing season produced 43.06 bushels.

285. The Seedbed for Winter Wheat. The value of plowing for winter wheat is indicated by several experiments. Kansas Station [21] reports an 8-year average where wheat was grown continuously,—the disked seedbed yielded 6.8 bushels, plowing 3 inches yielded 12.7, and plowing 7 inches yielded 13.5 bushels.

Missouri Station reports [22] that as a 3-year average winter wheat grown after soybeans with no preparation yielded 20.8 bushels; harrowing only, 20.1 bushels; double disked, 20.2 bushels; single disking and harrowing, 22.5 bushels.

At North Platte, Nebraska,[23] the average acre yield of wheat for an 8-year period was as follows:

Disked, no plowing	12.8	bushels
Late fall plowed, packed	14.7	"
Late fall plowed, not packed	13.4	"
Early fall plowed, packed	18.6	"
Early fall plowed, not packed	14.3	"
Wheat drilled between rows of corn	17.1	"

In Ohio [24] winter wheat yielded 26.01 bushels when planted on disked ground and 29.58 bushels when plowed. The plowing was done September 16.

Different seedbed treatments compared for a period of 4 years at the Oregon Station,[25] including 24 tests under each treatment, shows the following average yields of winter wheat per acre: early fall plowing, 28 bushels; late fall plowing, 25 bushels; disk plowing, 25.7 bushels; plowing first of April, 29.9 bushels; plowing the first of May, 27 bushels; plowing the first of June, 22 bushels.

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[20] Hutchinson, W. L.—"Corn—Varieties, Ear-Row, and Limiting Factor Tests." *S. C. Agr. Expt. Sta. Bul. 186.* 1916.

[21] Sewell, M. C.—"Tillage: A Review of the Literature." *Jour. Amer. Soc. Agron.* Vol. 11, p. 280. 1919.

[22] Helm, C. A., and Stadler, L. J.—"Productive Methods for Wheat in Missouri." *Mo. Agr. Expt. Sta. Bul. 188.* 1921.

[23] Zook, L. L.—"Winter Wheat Seedbed Preparation." *Nebr. Agr. Expt. Sta. Bul. 178.* 1921.

[24] Thatcher, L. E.—"Wheat, Cultural Notes." *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 7, No. 9-10, p. 143. 1922.

During each of the 4 years the plots plowed June 1, without previously being disked, produced wheat with a high percentage of starchy "yellow berry" kernels, while the plots sown on the same day but plowed April 1 produced wheat with no starchy "yellow berry" kernels. Early fall plowing and early spring plowing gave yields about equal in this test.

In a 1-year test in Montana,[26] wheat drilled between the rows of corn yielded 17.1 bushels, while on fallow land the yield was 18.9 bushels.

286. The Seedbed for Spring-sown Small Grain. A comparison of disking and plowing corn stubble for wheat and oats has been made for 16 years at the Dickinson Substation in North Dakota.[27] Spring wheat yielded 19.7 bushels on disked corn land and 19.3 bushels on plowed corn land. Oats yielded 39.8 bushels on disked corn land and 35.3 bushels on plowed corn land.

In another experiment at the same station comparison has been made with wheat and oats following fallow and following green manure crops. As a 16-year average, spring wheat has yielded 21.5 bushels after fallow and 17.4 bushels after green manure. Oats have yielded 45.5 bushels after fallow and 42 bushels after green manure.

North Dakota [28] reports a comparison of disking and plowing corn land for wheat and oats. The work has been carried out at each of 5 substations. The yields reported are in bushels per acre and are a combined average of 8 years at one station, 7 years at another, 6 years at another and 4 years at each of the two others.

	Combined Average, All Stations	
	Wheat Yield Bushels	Oats Yield Bushels
Disking corn land	18.3	38.6
Plowing corn land	18.3	35.9

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[25] Stephens, D. E., and Hill, C. E.—"Dry Farming Investigations at the Sherman County Branch Experiment Station." *Ore. Agr. Expt. Sta. Bul. 144.* 1917.

[26] Atkinson, Alfred, and Nelson, J. B.—"Winter Wheat." *Mont. Agr. Expt. Sta. Bul. 100.* 1914.

[27] Moomaw, Leroy—"Dickinson Substation Report for the Years 1922 and 1923." *N. Dak. Agr. Expt. Sta. Bul. 189.* 1925.

[28] Thysell, John C., *et al.*—"Dry Farming Investigations in Western North Dakota." *N. Dak. Agr. Expt. Sta. Bul. 110.* 1915.

Nebraska[29] reports yields without reference to the previous crop when the seedbed was plowed at different times or prepared in other ways.

286a. Time and method of seedbed preparation under dry-land conditions. Nebraska.

	FALL PLOW	SPRING PLOW	DISK	SUMMER FALLOW
Spring wheat	11.6	10.5	10.4	16.8
Corn	14.5	14.1	...	20.8
Oats	17.8	18.5	17.9	27.4
Barley	17.1	15.9	13.4	26.7

Montana[30] reports, in Table *286b*, yields of spring wheat, oats, and flax on disked corn land compared with yields on plowed corn land for the years 1909-1918, inclusive.

286b. Seedbed preparation for spring grains. Montana.

CROP	AV. NO. OF YEARS	DISKED BU.	FALL PLOWED BU.	SPRING PLOWED BU.
Spring wheat	9	22.8	21.6	21.4
Oats	9	52.4	...	48.9
Flax	4	13.0	10.5	11.5

The Bureau of Plant Industry,[31] United States Department of Agriculture, gives the yields with reference to various times and methods of seedbed preparation in the Texas Panhandle, in Table *286c*.

286c. Time and method of seedbed preparation. Amarillo, Texas.

	4-YEAR AVERAGE YIELD SPRING OATS	4-YEAR AVERAGE YIELD BARLEY	4-YEAR AVERAGE YIELD CORN
Shallow spring plow	16.06	6.7	9.65
Deep fall plow	19.89	10.23	11.58
Clean summer fallow	31.00	15.90	11.43
Deep fall plow and subsoil	15.77	7.39	11.51
Listed, dragged level for small grain, not for others	18.82	7.41	13.38
Disked and stubbled in after milo.........	15.00	....	....
Disked and stubbled in after kafir........	14.35	....	....
Disked and stubbled in after corn	16.89	6.43	....
Deep fall plowing after spring wheat......	22.46	....	9.31
Deep spring plowing after spring wheat...	19.71	6.81	7.82
Deep spring plowing after corn............	19.27	....	....

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[29] Snyder, W. P., and Osborn, W. M.—"Rotations and Tillage Methods in Western Nebraska." *Nebr. Agr. Expt. Sta. Bul. 155.* 1915.

[30] Baird, W. P.—"Corn Experiments at the Judith Basin Substation." *Mont. Agr. Expt. Sta. Bul. 132.* 1919.

[31] Ross, John F., and Leidigh, A. H.—"Cereal Experiments in the Texas Panhandle." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 283.* 1918.

287. The Seedbed for Oats. Ohio reports[32] work on the seedbed preparation of oats, 15-year average; 8 tests each year in Table *287a*.

287a. Plowing or disking versus seeding on corn stalk land with no preparation. Ohio.

Preparation	Yield		Per Cent Grain to Straw
	Grain, Bu.	Straw, Lbs.	
Ground disked	52.8	2776	37.7
Ground plowed	52.9	2782	37.5
No preparation	47.4	2723	35.8

Missouri reports[33] the yield of oats with different methods of seedbed preparation in Table *287b*.

287b. Preparing a seedbed for oats. Missouri.

Treatment	Method of Seeding	2-Yr. Average Yield Warrensburg	3-Yr. Average Yield Shelbina
Double disked and harrowed..............	Drilled	19.9	18.5
Fall plowed 6 inches.....................	Drilled	29.7	....
Spring plowed 4 inches, double disked	Drilled	24.1	14.8

Minnesota reports[34] comparisons of disking, spring plowing, and fall plowing, for oats and corn, 5-year average yields in rotations in Table *287c*.

287c. Methods of seedbed preparation. Minnesota.

Tillage Method	Manure Tons	Yields per Acre		
		Oats, Bu.	Hay, Tons	Corn, Bu.
Double disk corn land for oats, fall plowing for oats	6	61.56	2.89	57.92
Double disk corn land for oats, fall plowed for corn, no manure	0	60.78	2.74	52.54
Same manure on meadow	6	65.73	2.88	54.64
Same meadow pastured	6	63.91	....	55.34
Double disk corn land for oats, spring plow for corn	6	63.79	2.98	57.18
Fall plow for oats, fall plow for corn	6	63.65	2.85	56.31
Spring plow for oats, fall plow for corn	6	62.03	2.61	56.13
Double disk corn land for oats, fall plow for corn	6	58.24	2.65	49.65

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[32] Williams, C. G.—"Forty-second Annual Report for 1922-23." *Ohio Agr. Expt. Sta. Bul. 373*. 1923.

[33] Helm, C. A., and Stadler, L. J.—"Productive Methods for Oats in Missouri." *Mo. Agr. Expt. Sta. Cir. 105*. 1922.

[34] Arny, A. C.—"Crop Rotation Investigations." *Minn. Agr. Expt. Sta. Bul. 170*. 1917.

Kansas reports[35] various means of seedbed preparation for oats as an 8-year average in Table *287d.*

287d. Seedbed preparation for oats, eight-year average. Kansas.

METHOD OF SEEDBED PREPARATION	YIELD BUSHELS PER ACRE
Spring plowed, seed drilled in	31.1
Fall plowed, seed drilled in	31.2
Not plowed, seed drilled in	25.5
Not plowed, seed cultivated in	26.4
Not plowed, seed disked in	22.1
Not plowed, seed listed in	24.1
Disked, seed drilled in	24.0

Illinois[36] tested a compact and loose seedbed for oats. This is reported in Table *287e.*

287e. Compact and loose seedbed for oats. Illinois.

PREPARATION OF SEEDBED	COMPACTNESS	YIELD OF OATS, BUSHELS PER ACRE	
		1888	1889
1. Fall plow, seeded, lightly covered with disk, harrowed once	Very compact	...	40.0
2. Disked, seeded, disked, harrowed twice	Compact	60.0	44.4
3. Disked, seeded, disked, harrowed	Medium loose	66.3	47.8
4. Disked 3 times, seeded, disked, harrowed	Very loose	60.6	44.1

The Mississippi Station[37] compared different methods of preparing the seedbed for oats through a 2-year period. The results are given in Table *287f.* (257-273)

287f. Methods of preparing the seedbed for oats. Mississippi.

METHOD OF PREPARATION AND SEEDING	YIELD, BUSHELS PER ACRE	
	1911	1912
1. Sown broadcast on unprepared land (covered with a turning plow, then harrowed)	17	24.0
2. Same as above except disked to cover	14	18.9
3. Plowed, harrowed, broadcast, disked to cover	19	26.6
4. Same as No. 3, drilled	31	39.5
5. Same as No. 3, except open-furrow method used (big shovel opens furrow; furrow is not filled)	29	37.0

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[35] Georgeson, C. C., *et al.*—"Experiments with Oats." *Kans. Agr. Expt. Sta. Bul. 74.* 1897.

[36] Hunt, Thomas F.—"Field Experiments with Oats, 1889." *Ill. Agr. Expt. Sta. Bul. 7.* 1889.

[37] Ricks, J. R.—"Experiments with Small Grains." *Miss. Agr. Expt. Sta. Bul. 171.* 1915.

288. The Seedbed for Spring Wheat. Hardies and Hume [38] report comparisons of several different methods of preparing the seedbed for spring wheat at the Eureka Substation in South Dakota. Seven-year average yields are given for the various methods in Table *288a*.

288a. Seedbed preparation for wheat; seven years' average. South Dakota.

PLOT	SEEDBED PREPARATION	YIELD, BUSHELS PER ACRE
1	Wheat on summer-fallowed land	18.5
2	Wheat following checked corn	19.6
3	Wheat following drilled corn	21.8
4	Wheat and sweet clover following checked corn	19.2
5	Wheat after listed corn	20.7
6	Wheat after wheat, spring plowed	17.5
7	Wheat after wheat, fall plowed	14.7
8	Wheat after wheat, fall plowed every third year and disked the other 2 years	13.1

Nebraska reports [39] yields of spring wheat following corn as follows: land disked, 10.4 bushels; spring plowed, 10.2 bushels; fall plowed, 12.0 bushels. These yields are average for the years 1907 to 1914.

California reports [40] a comparison of disking and plowing the land for spring wheat. As an average for the 2-year test, the disked land has outyielded the plowed land by 3.1 bushels per acre, the disking yielding higher each year.

Iowa reports [41] a comparison of disking, spring plowing 4 inches deep, and spring plowing 8 inches deep for spring wheat. The 2-year average yield for the disked plot was 30.5 bushels; for the 4-inch plowing, 26 bushels; and for the 8-inch plowing, 25.3 bushels per acre.

289. The Seedbed for Barley. The Bureau of Plant Industry reports [42] results obtained with barley at 14 stations in the Great Plains area. Disking averaged highest, 18.5 bushels; spring plowing, 15.6 bushels; and fall plowing, 15.0 bushels per acre.

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[38] Hardies, E. W., and Hume, A. N.—"Wheat in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 222*, p. 17. 1927.

[39] Kiesselbach, T. A., and Ratcliffe, J. A.—"Oats Investigations." *Nebr. Agr. Expt. Sta. Bul. 160*, p. 43. 1917.

[40] Shaw, G. W.—"How to Increase the Yield of Wheat in California." *Calif. Agr. Expt. Sta. Bul. 211*. 1911.

[41] Atkinson, James—"Field Experiments." *Iowa Agr. Expt. Sta. Bul. 45*. 1900.

[42] Harlan, Harry V.—"Barley Culture, Uses and Varieties." *U. S. Dept. Agr. Farmers' Bul. 1464*. 1925.

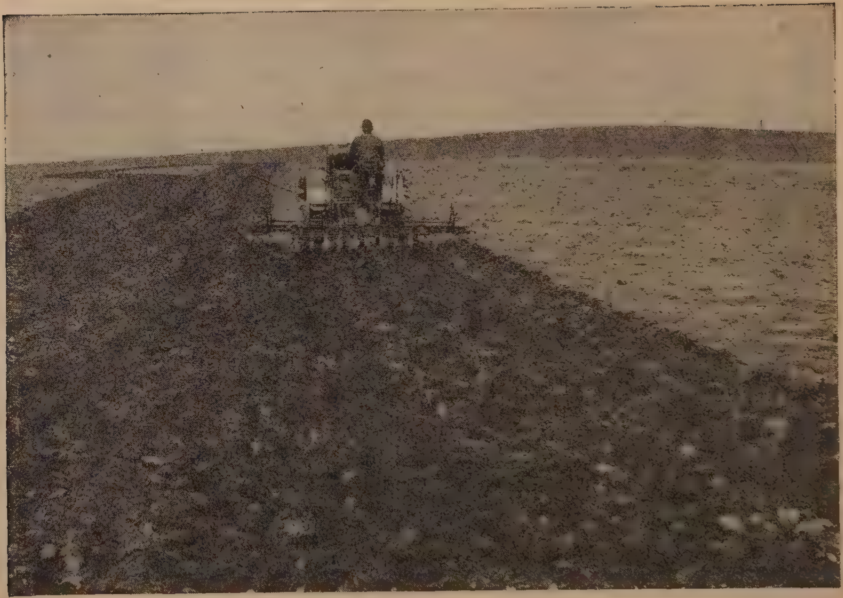

FIG. 67.—The spring-tooth harrow preparing fall plowed land for the seeding of barley. *Is it more desirable to plow in the preparation of the seedbed for certain small grains than for others? Explain.*

The results secured from different seedbed practices at each of 7 of these stations is shown in Table *289a*. (257 to 273)

289a. Methods of preparing the seedbed for barley. Judith Basin, Montana.

	NO. YEARS	FALL PLOW	SPRING PLOW	LISTED	SUB-SOILED	DISKED	FALLOW
Judith Basin, Montana	5	24.0	24.0	29.0	30.5	29.0	30.2
Belle Fourche, S. D. ..	6	7.6	8.3	7.7	8.0	12.2	12.6
Scottsbluff, Nebr.	2	14.0	15.4	14.4	15.0	18.6	27.6
Akron, Colo.	6	18.6	18.8	17.9	14.0	18.4	24.8
Hays, Kans.	6	13.6	11.2	12.7	14.6	14.1	19.3
Garden City, Kans. ..	5	6.9	4.3	8.3	6.9	8.9	11.0
Amarillo, Texas	6	8.2	5.7	6.1	6.8	6.6	12.6

290. Seedbed Preparation for Grain Sorghums. The United States Department of Agriculture has reported[43] the results of studies in Texas on the preparation of the seedbed for milo and kafir in Table *290a*. (262).

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[43] Ross, John F., and Leidigh, A. H.—"Cereal Experiments in the Texas Panhandle." *U. S. Dept. Agr. Plant Indus. Bur. Bul. 283.* 1913.

290a. Preparation of seedbed for grain sorghum. Texas.

Preparation and Condition of Field	4-Year Average Yield per Acre (Bushels)
Preparation for milo	
Shallow spring plowing after milo	24.96
Deep fall plowing after milo	22.54
Listed in spring after milo, planted at once	22.77
Deep fall plowing after winter wheat	28.39
Preparation for kafir	
Shallow spring plowing after kafir	14.11
Deep fall plowing after kafir	17.52
Listed in spring after kafir, planted at once	13.39
Deep fall plowing after winter wheat	19.95

STUDY QUESTIONS ON CHAPTER X

1. What changes are occurring in the soil air? How are these changes regulated?
2. Why did forcing air up through pot cultures increase the yield?
3. Does stirring the soil thoroughly increase aëration and stimulate yield under ordinary conditions? Why?
4. The seedbed required for various crops may depend upon their habit of growth. Group the standard crops as (1) those starting off slowly with a relatively long season and (2) those starting off rapidly with a short season of growth.
5. How would the demands for water of the above two groups of crops vary during different periods of the year? For plant nutrients? What type of seedbed would be demanded by each? Why?
6. What effects have the following on a plowed seedbed: the harrow; the disk; the roller; the cultipacker?
7. Describe a good seedbed for corn.
8. Why is listing a good dry-land method of seedbed preparation for corn? To what extent can this method be used in the central corn belt?
9. What differences do you note in seedbed requirements where the rainfall is limited as compared with sections where it is abundant. Why?

APPLICATION ASSIGNMENTS ON CHAPTER X

1. You are leaving Western Kansas to farm in Illinois. You have a two-row lister planter, a two-bottom plow, a disk and a harrow. What tools will you take with you? A neighbor who is moving to Louisiana wants to buy your lister planter at half its value as he says he can use it while you cannot. Is he right? Contrast these three sections in essentials of seedbed preparation.
2. You have grain stubble on a black loam soil. How deep will you plow? Why?

3. Following a relatively dry summer you harvest 66 bushels of corn per acre on fall-plowed land and 70 in the same field where spring-plowed. Why? With an abundance of rainfall throughout the summer would the relative yields have been different? Why?
4. In planting corn on land previously in potatoes, which is mellow and free of weeds, how will you prepare the seedbed? Why?
5. The rains in your section come in the late fall and late spring with dry weather during early spring and summer. How will you prepare the seedbed in order that the crops may have the most water available? Why?

CHAPTER XI

CULTIVATION OF CROPS

Cultivated or intertilled crops are almost universally included in cropping systems. In certain sections of the wheat belt wheat is grown continuously year after year; but, even here, cultivated crops are being advocated. One of the important advantages of including a cultivated crop in the rotation is in the control of weeds. The crops commonly grown in rows and cultivated are corn, cotton, sorghums, potatoes, peanuts, sugar beets, sugar cane, and tobacco. Soybeans, cowpeas, velvet beans, hemp, and other minor crops may be grown in rows for seed. In the past cultivation has been credited with many beneficial effects, some of which are not substantiated by experimental results.

Implements of Cultivation

291. Kinds of Cultivating Tools. Implements for cultivation vary widely in type and size. Among the horse-drawn implements the "Georgia Stock" and the double shovel are perhaps the simplest. When these implements are used, it is necessary to cross the field two or more times in cultivating one row. At the other extreme are implements which will handle several rows at a time. With a 4-row corn cultivator, motor operated, on the market in 1929, it was possible for one man to take care of over 250 acres of corn throughout the season.

"Georgia Stock." The Georgia Stock has handles and a beam much like an ordinary walking, turning plow, though the beam, of course, is much lighter. On the end of the beam a variety of shovels or sweeps may be used,—broad sweeps cutting 10 to 16 inches are common. The Georgia Stock is pulled by one horse and is easily handled around stumps, trees, and rocks. This implement is used rather generally throughout the cotton belt.

The double shovel is similar to the Georgia Stock; it has two shanks for shovel or sweep attachments. It is used in much the same way and for the same purposes as the Georgia Stock.

Shovel cultivators. The most widely used cultivators are equipped with 2 beams to which any number of shovels up to about 6 each may be attached. The 6-shovel cultivator is perhaps the most common type in use (3 shovels or sweeps on each beam). Sweeps are used extensively in the South for controlling crab grass and vining weeds. They are not ordinarily set very deep.

Disk cultivators. The disk cultivator has disks instead of shovels and is widely used on listed land. There are two general types of disk cultivators, the ordinary wheel type, and the sled type.

Surface cultivators. The surface cultivator uses blades or knives, and shears through the ground, cutting the weeds and grass without stirring the soil very much. The common practice in the Southwest of substituting "duck foot" sweeps for the shovels of an ordinary cultivator makes a surface cultivator out of an ordinary shovel cultivator.

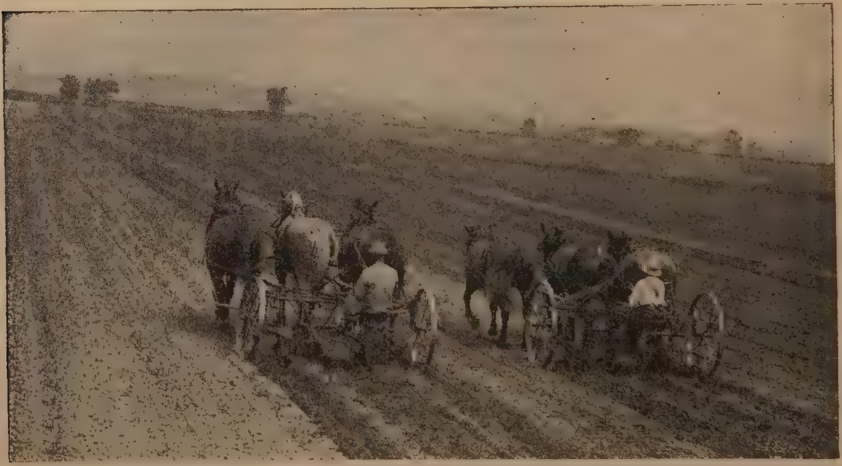

FIG. 68.—The two-row cultivator is rapidly becoming standard equipment on farms throughout the corn belt. *From data available, determine the cost per acre of plowing corn three times with a single-row cultivator as compared with the cost when a two-row cultivator is used. What factors other than labor cost may determine whether the use of a three-row cultivator is desirable?*

Other cultivators. The spike tooth harrow and the weeder are admirable for use early in the season. The harrow can be used before the corn is up and until it is 4 or 5 inches in height, while the weeder can be used until corn or similar crops are a foot or 18 inches in height. Either of these tools kills young grass and weeds effectively. The "A" harrow and "duck foot," or 5-shovel plow, are types made for cultivating between two rows and can be used for late cultivations when ordinary cultivators cannot be used. The rotary hoe, a roller affair with curved, spade-like teeth, is coming into favor as a means of reducing the cost of cultivating rowed crops. It is particularly valuable where soils crust, as the harrow and weeder have little value under such conditions.

COST OF CULTIVATION

292. Equipment and Acres Covered per Day. In considering the increased yields which may result from certain cultural practices, the cost of the operation must have careful consideration. The cost of cultivating the different crops is almost directly correlated with the number of man or horse hours of labor required per acre per person. The United States Department of Agriculture has summarized data on the man and horse power required and the number of acres of corn and of cotton cultivated in a day when using various tools.[1] From these data it is possible to estimate the approximate labor cost for various operations, using such rates of hire as may prevail at any particular time or place. Data on the number of acres covered per day with different kinds of field machinery, some of which may be used in the cultivation of intertilled crops, are presented in Table *292a* (p. 244).

EFFECT OF DIFFERENT CULTURAL METHODS ON THE YIELD OF ROWED CROPS

In general, the purpose of cultivation is to aid in maintaining soil conditions which are favorable to the growth of the plant. There are a number of factors involved, some of which are better understood than others. Definite experimental results would not seem to justify the expense incurred by some of the most careful farmers in their cultivation practices. The cost of securing each unit of increase must have careful consideration. The results obtained by scraping the surface as compared with ordinary cultivation are of importance in indicating the chief function of cultivation.

293. Early Results from New York and Illinois. The New York Station in 1886[2] reported a comparison of different cultivation treatments for corn. Where weeds were allowed to grow, the yield of corn was 18.1 bushels; where the weeds were pulled but with no cultivation, the yield was 70.5 bushels; while on a third plot which was given normal cultivation plus hoeing to keep the weeds down, the yield was 56.8 bushels. The New York station reports that no data that they have ever published was so widely criticized and commented on as this. It further states: "Strangely enough, we have, during the existence of this station, been unable to obtain decisive evidence in favor of cultivation."

The Illinois Station[3] reports work on cultivation during the years

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[1] *U. S. Dept. Agr. Yearbook 1922*, pp. 1048-1065.

[2] Sturtevant, E. Lewis—"Weeds in Corn." *N. Y.* [*Geneva*] *Agr. Expt. Sta. Ann. Rept. 5*, pp. 50-51. 1886.

[3] Mosier, J. G., and Gustafson, A. F.—"Soil Moisture and Tillage for Corn." *Ill. Agr. Expt. Sta. Bul. 181*. 1915.

292a. The man and horse power required in cultivating corn and cotton and the acres covered per day with various implements.

LOCATION	TYPE OF PLOW	WIDTH OF ROW	NO. TIMES PER ROW	CREW		RATE PER DAY ACRES
				M.	H.	
	Corn Cultivation					
General U. S.		3½	2	1	1	4.9
General U. S.	One row	3½	1	1	2	7.9
Central Ill.	One row riding	3½	1	1	2	7.7
Central Ill.	Two rows riding	3½	½	1	3	13.3
Central Ill.	Two rows riding	3½	½	1	4	14.9
New York	One row walking	3½	1	1	2	6.4
Louisiana	Double shovel or Georgia Stock	3½	2	1	1	3.4
Louisiana	Double shovel or Georgia Stock	4	2	1	1	4.1
Louisiana	Double shovel or Georgia Stock	4½	2	1	1	4.1
Louisiana	Five-shovel type	4	1	1	1	7.9
Louisiana	Five-shovel type	5	2	1	1	4.7
Louisiana	One row walking	4	1	1	2	7.2
General U. S.	16 ft. spike tooth harrow	3½	..	1	4	36.4
General U. S.	8 ft. weeder	...	..	1	1	10.0
General U. S.	8 ft. weeder	...	..	1	2	14.3
Cotton belt	One row harrow	...	..	1	1	7.0
	Cotton Cultivation					
Georgia	Walking—barring off			1	1	3.0
Alabama	Walking—barring off			1	1	2.9
South Carolina ..	Walking—barring off			1	1	2.6
Texas	Walking—barring off			1	1.2	3.4
Louisiana	Scrapers, riding or walking			1	1	3.34
	Subsequent Cultivation (Cotton)					
Georgia	Walking or riding			1	1	3.4
Georgia	Walking or riding			1	2	5.6
Texas	Walking or riding			1	2	7.1
General U. S.	Walking plow			1	1	4.8
General U. S.	Walking or riding			1	2	7.5
	Cleaning Middles (Cotton)					
Georgia	Walking			1	1	6.0
Alabama	Walking			1	1	5.4
Texas	Walking			1	1	6.2
General U. S.	Chopping			1	0	1
General U. S.	Hoeing			1	0	1.2

1888 to 1893, and again in 1896. The results of this work are presented in Table *293a.*

293a. Methods of cultivating corn compared. Illinois.

Nature of Cultivation	7-Year Average Yield
None, weeds scraped off with a hoe	68.3
Shallow, 4 or 5 times	70.3
Deep, 4 or 5 times	66.7
Shallow, 12 to 14 times	72.8
Deep, 12 to 14 times	64.5

In 3 years out of 7 the weed-scraped plot gave the highest yield, while in 4 years ordinary shallow cultivation yielded highest.

294. Later Work on Corn Cultivation at the Illinois Station. The Illinois Station reports[4] results from work continued through the years 1916 to 1921, inclusive, as shown in Table *294a.*

Blades stirred the soil from 1 to 1.5 inches deep; shovels stirred the soil from 2 to 3 inches deep. The soil in these studies was a brown silt loam representative of the gently undulating areas of the corn belt in Illinois.

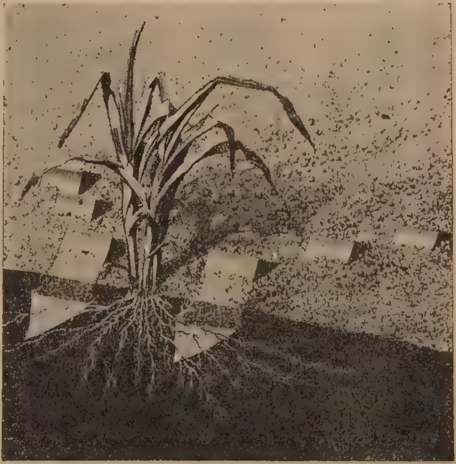

FIG. 69.—*How deep and how close to the corn is it safe to plow? Do yield results indicate material differences in yield when corn is plowed deep early in the season and shallow later? Under average conditions, how many times in a season is it profitable to cultivate corn?*

294a. Method of cultivating corn as influencing the yield; bushels per acre. Illinois.

Treatment	1916	1917	1918	1919	1920	1921	6-Yr. Average
1. Weeds allowed to grow	0.05	13.1	1.9	2.9	9.6	14.5	7.0
2. Weeds scraped with hoe	28.6	66.1	59.7	56.0	56.4	53.1	53.3
3. Cultivated—blades	32.0	60.7	56.2	61.2	51.4	56.4	53.0
4. Cultivated—shovel	32.6	59.6	55.1	55.5	50.2	53.4	51.1
Annual rainfall; inches ..	29.7	32.2	43.3	35.3	29.3	41.7	

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[4] Wimer, D. C., and Harland, M. B.—"The Cultivation of Corn." *Ill. Agr Expt. Sta. Bul. 259.* 1925.

One-half of each of the plots had been fertilized with manure, phosphorus, and lime. The differences in yields on the fertilized plots and on the unfertilized plots should indicate whether the differences were due to a lack of nutrients or to some other factor. The yields of corn are presented in Table *294b* for the first and second years in the rotation of corn, corn, oats, and clover.

294b. The effect of different methods of cultivation on the yields secured from fertilized and from unfertilized plots; also from first and from second years in corn: six-year average. Illinois.

	UNFERTILIZED	FERTILIZED	1ST YEAR CORN	2ND YEAR CORN
Weeds allowed to grow	7.0	11.6	6.7	7.2
Weeds scraped	53.3	55.6	56.7	49.9
Cultivated, blades	53.0	58.1	58.8	47.1
Cultivated, shovels ...	51.1	59.5	57.3	44.8

In tests at Illinois, 1907 to 1915, certain plots where the weeds were allowed to grow were irrigated and compared with similar plots not irrigated. Where the weeds were allowed to grow without irrigation, the yield was 9.3 bushels for a five-year average; where irrigation water was applied, the yield was 14.9 bushels. In the same series of plantings ordinary shallow cultivation, 3 times, gave a yield of 48 bushels without irrigation and 60.2 bushels with irrigation.

In these studies the effect of weeds on crops, with reference to their use of food material or nutrients and with reference to moisture utilization, can be determined. The effect of weeds from the standpoint of other growth factors, such as light, temperature, air of the soil, and other factors influenced by competition, is not indicated.

295. Missouri Cultivation Experiments. The Missouri Station reports [5] the results of work on corn cultivation carried on at 4 state substations.

295a. Cultivation at various depths compared with no cultivation (surface scraping). Missouri.

KIND OF CULTIVATION	NO. OF CULTIVATIONS	SHELBINA 3-YEAR AVERAGE	WARRENSBURG 3-YEAR AVERAGE	MARYVILLE 3-YEAR AVERAGE	SPRINGFIELD 1 YEAR	AVERAGE OF ALL
Shallow	4	22.5	23.8	45.7	28.4	30.1
Late	6	21.4	23.2	37.9	28.3	27.7
Deep	4	21.1	21.8	33.7	18.0	23.6
None; surface scraped	0	Not included	25.6	58.9	34.9	39.8

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[5] Helm, C. A.—"Corn in Missouri: II. Field Methods that Increase the Corn Crop." *Mo. Agr. Expt. Sta. Bul. 185.* 1921.

296. Summary of Station Reports on Cultivation *vs.* Scraping. Similar work, comparing different methods of cultivation, has been done at several other stations. In most instances corn was the crop grown. The results obtained at a number of these stations are summarized in Table *296a*.

296a. Yields resulting from ordinary cultivation, surface scraping, weed pulling, and no cultivation; bushels per acre. Summary.

STATION AND BUL. NO.	NO. YEARS	CROP	WEEDS GROWING	PULLED	SCRAPED	ORDINARY CULTIVATION
S. C.; 61 (1899)	2	Corn			62.0	62.9
Mo.; 14 (1890)	2	Corn		63.8		67.0
Ill.; 181 (1915)[a]	5	Corn	6.3		18.9	19.1
Ill.; 259 (1925)[b]	8	Corn	9.4		51.4	47.0
Kans.; 238 (1926)	9	Corn			48.4	49.2
Okla.; 150 (1925)		Kafir	13.02		22.52	22.09
Mich. (1920)[c]	3	Potatoes			94.13	100.00
Mich. (1920)[c]	3	Corn			107.06	100.00
Minn.; 149 (1915)	3	Corn	9.02		64.17	48.15
Va.; 214 (1917)	4	Corn	8.17		49.04	59.43
Ohio; 431 (1929)	3	Corn[d]			49.2	57.1
	3	Corn[e]			72.7	66.9

[a] Wayne county.
[b] Urbana, Illinois.
[c] *Mich. Quarterly Bul. 3,* Vol. 2, p. 142. Feb. 1920.
[d] Brooklin silty clay loam.
[e] Miami silty clay.

297. Summary of Farmer Comparisons. Cates and Cox[6] report results obtained through the coöperation of a large number of farmers in various parts of the United States who made comparisons on their farms of ordinary cultivation and weed scraping,—removal of weeds with a hoe. On the scraped or uncultivated plots the hoe was used with a horizontal stroke to cut off the vegetation at the surface, particular care being taken to stir as little soil as possible. On the plots receiving ordinary cultivation all weeds and grass which persisted were removed by topping with a hoe.

In 124 such trials, when the yield of grain from ordinary cultivation was given a value of 100, the yield on the uncultivated or weed scraped plots averaged 99.1.

In many of the trials the soil type was indicated. The types were grouped into 4 classes, medium black loam, heavy black loam, clay, and sand. On the medium black loam the cultivated plots gave the larger yield 12 times and the smaller yield 5 times; on the heavy black loam the larger 11 times and the smaller 10; on the clay the larger 15 times and the smaller 8; and on sand the larger 14 times and the smaller 12. In a few cases on all types of soil there was no appreciable difference in the yield of the two methods of treatment. The results of these comparisons, summarized by states, are presented in Table *297a*.

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[6] Cates, J. S., and Cox, H. R.—"The Weed Factor in the Cultivation of Corn." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 257.* 1912.

297a. Ordinary cultivation compared with no cultivation, but with the weeds controlled by scraping the surface; grouped by states; yield of scraped plots expressed in per cent of yield from ordinary cultivation. Summary.

State	No. of Experiments	Value of Yield from Scraped Plots When Cultivated Plot—100 Per Cent
Iowa	7	102.72
Illinois	8	94.74
Indiana	9	105.36
Kentucky	9	91.28
Maryland	1	109.20
Michigan	7	116.26
Minnesota	1	100.00
Missouri	3	103.20
Nebraska	1	101.90
New Hampshire	10	112.71
South Carolina	12	99.07
Virginia	9	88.51

The observation was made that the weeds stopped growing sooner on the plots which were scraped than on those which were cultivated. The authors believe that the advantage, if there was any, was slightly in favor of the cultivated plots. The water ran off surface-scraped plots more than plots receiving ordinary cultivation. In some cases the weeds were not thoroughly controlled on the scraped plots, and this may have been an important factor.

298. Frequency and Distribution of Cultivation. Kiesselbach[7] *et al* state that weed control is the main consideration in corn cultivation. In a 6-year comparison of various frequencies, plats given 0, 1, 2, 3, and 4 normal cultivations respectively, yielded 7.1, 21.6, 33.6, 35.9, and 37.2 bushels per acre. Continued late cultivation after corn was normally laid by reduced the yield 2 bushels per acre. The corn plots that were merely scraped by means of a hoe to prevent weed growth yielded 2.1 bushels per acre less than corresponding corn which received 4 normal cultivations.

Bull[8] of the Minnesota Station reports the influence on the yield of corn of cultivating a different number of times in Table *298a*.

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[7] Kiesselbach, T. A., Anderson, Arthur, and Lyness, W. E.—"Tillage Practices in Relation to Corn Production." *Nebr. Agr. Expt. Sta. Bul. 232.* 1928.

[8] Bull, C. P.—"Corn." *Minn. Agr. Expt. Sta. Bul. 149.* 1915.

298a. Number of cultivations for corn. Average 1908, 1909, 1910. Minnesota.

No. of cultivations	0	2	3	4	6	Hoed
Per cent barren stalks	25.2	9.7	21.7	5.8	5.7	7.9
Yield of corn per acre, bushels	9.02	45.69	48.15	59.07	62.71	64.17
Yield of stover per acre, pounds	2066.2	3210.0	3750.0	3896.0	3931.0	3761.0

McKillican[9] reports cultivation comparisons with corn at Manitoba, Canada, in Table *298b*. The corn was harvested at the proper stage for silage. The average annual rainfall was 17.54 inches.

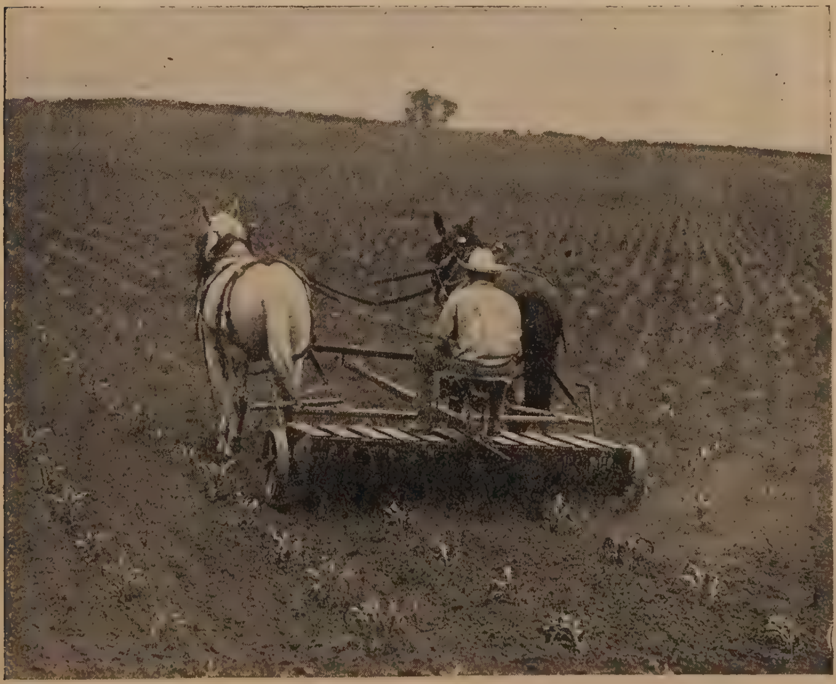

Fig. 70.—The rotary hoe is a new implement which is being used very extensively to decrease the cost of cultivation. *What is the primary reason for cultivating corn and can all other factors be ignored?*

In Ohio[10] corn which received ordinary cultivation distributed normally during the season produced 52.8 bushels per acre; 3 ordinary cultivations 2 days apart, 51.2 bushels; 12 days apart, 55.3 bushels. Each period of cultivation was started when it was believed that it would do the most good.

[9] McKillican, W. C.—"Cultural Experiments with Corn." *Canada Expt. Farms, Brandon (Man.) Farm Rpt. Supt. 1923.*

[10] Lazenby, Wm. R.—"Experiments with Corn." *Ohio Agr. Expt. Sta. Ann. Rept. 6*, p. 163. 1887.

298b. Methods of cultivating corn. Manitoba, Can.

Treatment	6-Year Average—Tons per Acre
Harrowed when coming up	11.1
Cultivated once	11.2
Cultivated 3 times	11.7
Cultivated 6 times	12.5
Cultivated 3 times and hoed	13.0
Cultivated 6 times and hoed	13.1
Harrowed when coming up, cultivated 3 times and hoed	12.5
Harrowed when coming up, and again when 4 in. high, cultivated 3 times and hoed	11.2

Studies of frequency of cultivation as affecting yield have been made at a number of stations, and a number of them are summarized in Table *298c* on p. 251. Attention should be given to the number of years through which a particular study has extended.

299. Early and Late "Laying By." In Mississippi[11] as an average for 2 years, corn laid by when it was waist high averaged 32.6 bushels per acre as compared with 46.4 bushels from corn laid by when it was beginning to tassel.

Salmon[12] reports that as an average for 9 years corn yielded 49.2 bushels per acre with ordinary cultivation; and, where this was followed by one-horse cultivation whenever it seemed desirable, the yield was also 49.2 bushels. When ordinary cultivation was followed by one-horse cultivation every 10 days during the summer, the yield was 48.1 bushels.

Removing witch grass by hoeing after the corn was laid by increased the yield of shelled corn 20 bushels per acre in New Hampshire[13] as compared to the unhoed plots where the grass was matted in the rows.

In South Dakota at the Highmore Substation[14] corn hoed in July yielded 26.1 bushels per acre; that hoed in August, 19.9 bushels; and that not hoed, 19.9 bushels. All plots received the standard cultivation. The hoeing was for the purpose of getting out the weeds left in the field after cultivation.

300. Level Cultivation and Ridging Compared. In certain sections it is the common practice to hill or ridge corn at the last cultivation. Tests have been made in several states with reference to this method of cultivation.

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[11] Ricks, J. R.—"Corn." *Miss. Agr. Expt. Sta. Bul. 170.* 1915.

[12] Salmon, S. C.—"Corn Production in Kansas." *Kans. Agr. Expt. Sta. Bul. 238.* 1926.

[13] Burkett, Charles Wm.—"Corn Culture." *N. H. Agr. Expt. Sta. Bul. 71.* 1900.

[14] Hume, A. N.—"Corn Culture in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 181.* 1918.

298c. The effect of frequency of cultivation on crops; yields in bushels per acre except as indicated. Summary.

STATION AND REFERENCE	NO. YEARS	CROP	NO. OF CULTIVATIONS						
			1	2	3	4	5	6 to 8	Over 10
Ohio Ann. Rpt. 6	3	Corn			20.32		22.59	18.19	
Illinois 181	5	Corn shallow				70.3			72.8
	5	Corn deep				66.7			64.5
Md. 62		Corn		53.0	53.7				
Va. 214		Corn			59.4		58.7		
Minn. 149	3	Corn		45.7	48.2	59.1	62.7	64.2	
Ky. 272	10	Corn shallow			55.8			55.5	
Ky. 272	10	Corn deep			56.1			56.2	
N. H. 71	1	Corn					79.1		80.6
Kans. 64	3	Corn	30.5	47.8	35.1	48.6	34.4	45.5	
Okla. 150	7	Kafir shallow			22.1		23.1		
Okla. 150	7	Kafir deep			20.1		21.3		
Ariz. 84		Milo	572#	836#	572#		748#	748#	
Brandon, Man. 1924 Rpt.	7	Corn	11.5		12.5T.			13.2T.	
Brandon, Man. 1921 Rpt.	7	Potatoes			274.3			321.7	
Ill. 37th Ann. Rpt.	7	Corn		100%	111%	113.1%	111.8		

Foster and Merrill in Utah[15] report an experiment with reference to hilling corn *vs.* level cultivation with the crop grown under irrigation.

300a. Effect of ridging on yield of corn. Utah.

	7-Year Average Yield	
	Grain	Fodder
Level tillage one way, corn checked	60.09	4718
Level tillage both ways, corn checked	65.81	4520
Hilled one way, corn checked	59.73	4318
Hilled both ways, corn checked	63.02	4549

Ricks[16] reports a test in Mississippi in which level cultivation of corn yielded 42.1 bushels and ridged cultivation 30.3 bushels as a 2-year average.

301. Depth of Cultivation. Work has been done in many states comparing the yields obtained by cultivating crops to different depths. The yield data from a number of these studies are summarized in Table *301a* on p. 253.

Nelson and McClelland[17] report the results obtained from different methods of cultivation at the Arkansas Experiment Station over a period of 18 years. The yield of corn obtained from different methods of cultivation is compared with that secured from a standard method,—corn plowed to a medium depth 3 times before tasseling. The results are given in Table *301b*.

301b. Yield of corn in bushels per acre resulting from different methods of cultivation with the yield obtained from the ordinary practice of three medium cultivations, which is considered the standard. Arkansas.

Cultural Treatments	No. of Tests	Bushels + or — Yield from Three Plowings
No cultivation	17	—31.3
Very shallow cultivation[a]	15	— 2.0
Scraped with hoe	25	— 2.3
Medium deep cultivation	15	+ 1.0
Deep cultivation	25	— 1.87
Shallow, then deep	5	+ 1.4
Deep, then shallow	13	+ 1.4

[a] *Very shallow* cultivation was limited to one inch in depth.

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[15] Foster, Luther, and Merrill, Lewis A.—"Corn Experiments." *Utah Agr. Expt. Sta. Bul. 66.* 1900.

[16] Ricks, J. R.—"Corn." *Miss. Agr. Expt. Sta. Bul. 170.* 1915.

[17] Nelson, Martin, and McClelland, C. K.—"Cultivation Experiments with Corn." *Ark. Agr. Expt. Sta. Bul. 219.* 1927.

301a. *Effect of the depth of cultivation on yields of crops; bu. per acre, except cotton, which is in pounds. Summary.*

STATION AND REFERENCE	NO. OF YEARS	CROP	DEPTH OF CULTIVATION							
			1 in.	2 in.	3 in.	Shallow	4 in.	5 in.	6 in.	Deep
Iowa Bul. 55	2	Corn		82.4				79.1		
Ill. Bul. 181	7	Corn				70.3				66.2
Ohio Bul. 140	9	Corn	60.4				56.4			
Ohio Bul. 431	4	Corn		80.4[b]	93.3			83.2		
Ind. Bul. 39	2	Corn	58.7	61.0	57.4					
Md. Bul. 46	3	Corn				47.1				48.5
Md. Bul. 46	3	Potatoes				110.3				109.5
Md. Bul. 62	6	Corn			52.2				54.2	
Mo. Bul. 14	2	Corn		66.9				53.5		
Mo. Bul. 185	3	Corn				30.1		23.6		
Kansas Bul. 64										
Listed	4	Corn				29.3				29.7
Surface planted	4					27.0				27.3
Kansas Bul. 147	4	Corn		51.3				51.4		
Okla. Bul. 150	8	Kafir				22.09				20.06
Okla. Bul. 44	1	Corn		47.0				44.5		
S. Car. Bul. 63[a]	3	Cotton				1064				956.3
Miss. Bul. 83	1	Corn			30.09			31.3		
Ga. Bul. 128		Corn				23.2				19.7
N. Dak. Bul. 51	2	Corn		31.12				32.1		
Ky. Bul. 272	10	Corn				55.8				56.1
Utah Bul. 66	7	Corn				52.9				57.05

[a] State Department Bulletin.
[b] 1 to 2 inches reported under "2 inch," 2 to 3 inches under "3 inch," 4 to 6 inches under "5 inch."

Sheppard and Ten Eyck[18] report that, at the North Dakota Station as an average for 2 years, shallow early cultivation with deep cultivation later, yielded 34.3 bushels; while deep cultivation early and shallow cultivation later yielded 37.5 bushels.

Kansas[19] reports the effect on the yield of corn of deep and of shallow cultivation early and late in the season as compared with "ordinary shallow cultivation."

301c. Depth of cultivation and yield of corn; four-year average. Kansas.

CULTIVATION	GRAIN BU. PER ACRE	STOVER LBS. PER ACRE
Ordinary shallow[a] cultivation	51.3	3427
Shallow early, deep later	52.1	3215
Deep[b]	51.4	3213
Deep early, shallow later	50.0	3404

[a] Shallow cultivation 1½ inches.
[b] Deep cultivation 3½ to 4 inches.

302. Kafir Cultivation. Oklahoma. Murphy[20] reports rather extensive cultivation work with kafir in Oklahoma. Shallow cultivation varied from 0 to 3 inches in depth; deep cultivation ranged from 4 to 6 inches; the soil was not disturbed any more than could be helped when the weeds were scraped. The results given in Table *302a* are for a 7-year period on ordinary upland soil.

302a. Various methods of cultivation compared by the yield of kafir produced. Oklahoma.

TREATMENT	7-YEAR AVERAGE YIELD OF KAFIR	
	Grain, Bu.	Forage, Lbs.
No cultivation or hoeing	13.02	1907
Weeds scraped off with a hoe	22.52	3244
Cultivated deep after rains	21.48	3197
Cultivated shallow, 3 times	22.09	3332
Cultivated shallow, 5 times	23.14	3377
Cultivated shallow after rains	23.55	3429
Cultivated deep, 3 times	20.06	3034
Cultivated deep, 5 times	21.29	3192
Cultivated deep early and shallow later	20.38	3349
Cultivated shallow early and deep later	20.54	3664

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[18] Sheppard, J. H., and Ten Eyck, A. M.—"Corn Culture." *N. Dak. Agr. Expt. Sta. Bul. 51*, 1902.

[19] Ten Eyck, A. M., and Shoesmith, V. M.—"Indian Corn." *Kans. Agr. Expt. Sta. Bul. 147*, 1907.

[20] Murphy, H. F.—"Cultural Methods for Corn and Grain Sorghums on Oklahoma Soils." *Okla. Agr. Expt. Sta. Bul. 150*. 1925.

303. Types of Cultivators and Yield. The importance of the type of cultivating implement used may be judged by work at the Illinois Station continued through 10 years, comparing 4 of the cultivators used most generally throughout the corn belt. The average yields of corn in bushels per acre for the 10-year period, 1912 to 1921 inclusive, were as follows: small shovel, 49.2; large shovel, 48.2; Tower (gopher), 49.3; disk, 49.5. These tools were compared under uniform conditions as to soil and number and times of cultivation.

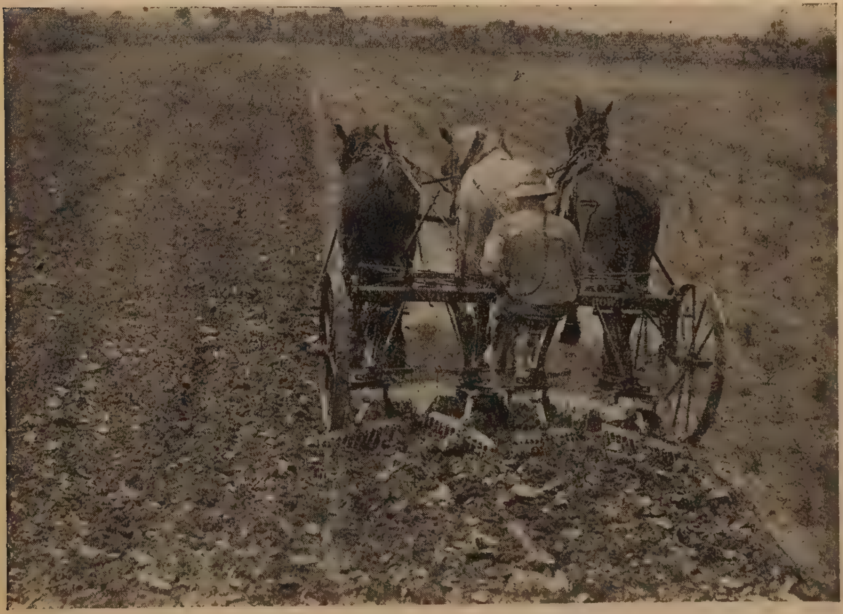

FIG. 71.—Plowing small corn with gopher (knife blade) shovels. *Some growers prefer one type of shovel and others prefer another. Why? Do the yield data show material differences in yield from different types of cultivators?*

304. The Effect of Cultivation on the Roots of the Plant. Morrow and Hunt[21] report 3 years' study of the roots of the corn plant as affected by cultivation. The plants were grown on black loam soil which had been plowed 6 inches deep. A trench was dug beside the plant and the soil washed away so the roots could be examined 6 inches from the plant.

The first year an examination of the roots when the plants were 26 inches high showed that a 3-inch cultivation would have injured one-fourth of the roots, while a 4-inch cultivation 6 inches from the plant would have broken practically all. The second and third years, two-

[21] Morrow, G. E., and Hunt, T. F.—*Ill. Agr. Expt. Sta. Buls. 4, 8* and *13.* 1889, 1890, and 1891.

thirds of the roots would have been broken by cultivating 4 inches deep. In the third year, over one-seventh of the roots would have been injured by cultivating 2 inches deep.

The effect on yield of cutting the corn roots in the surface soil to a depth of 4 inches at a distance of 6 inches on all sides of the hills was determined,[22] as shown in Table *304a*. **(117)**

304a. Root pruning of corn and its effect on yield of ear corn; bushels per acre. Illinois.

TREATMENT	YIELD—4-YR. AVERAGE
Roots not pruned; shallow, ordinary cultivation	84.1
Roots pruned; shallow, ordinary cultivation	68.2
Roots not pruned; weeds scraped with a hoe	80.7
Roots pruned; weeds scraped with a hoe	63.8

305. Cultivation of Small Grain. A number of stations have determined the effect on yield of harrowing small grain. The yields from a number of stations are summarized in Table *305a*.

305a. Effect of harrowing in the spring on the yield of small grains; bu. per acre. Summary.

STATE AND REFERENCE	CROP	NO. OF TIMES TREATED	HARROWED	NOT HARROWED	NO. OF YEARS
Nebr. Bul. 104........	Winter wheat	1	37.3	38.2 Drilled	4
Nebr. Bul. 104........	Winter wheat	1	35.3	38.2 Broadcast	4
Utah [a]	Winter wheat	1 or 2	15.99	17.05	5
Mont. Bul. 100	Winter wheat	2 to 4	21.68	19.58	3
Ore. Bul. 190	Winter wheat	1	26.6	27.6	9
Nebr. Bul. 113........	Oats	1 to 3	51.4	46.6	7

[a] *U. S. Dept. Agr. Dept. Bul. 157.*

At the Nebraska Station[23] winter wheat rolled in the spring produced 43.3 bushels in comparison with a plot not rolled which produced 38.2 bushels. Wheat both rolled and harrowed produced 40 bushels.

306. Cultivation of Alfalfa. The Kansas Station[24] reports the yields of alfalfa at the Fort Hays Station cultivated in different ways; also the yields of alfalfa grown under the same conditions and not cultivated.

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[22] Mosier, J. G., and Gustafson, A. F.—"Soil Moisture and Tillage for Corn." *Ill. Agr. Expt. Sta. Bul. 181.* 1915.

[23] Montgomery, E. G.—"Cultivation of Small Grains." *Nebr. Agr. Expt. Sta. Bul. 104.* 1908.

[24] Getty, R. E.—"Forage Crops in Western Kansas." *Kans. Agr. Expt. Sta. Bul. 225.* 1921.

306a. Cultivation of alfalfa. Kansas.

Treatment	4-Year Av. Yield Tons per Acre
No cultivation	2.15
Double disked and harrowed early in spring	2.21
Single disked and harrowed early in spring	2.15
Single disked in early spring and after each cutting	2.17
Single disked only in early spring	2.26
Renovator with hoe drill type of rounded shovels used in spring and after each cutting	2.03
Renovator used only in spring	2.10
Spring tooth harrow with 1¼ inch teeth used early in spring	2.08
Spring tooth harrow with 2½ inch flat shovels used in early spring	2.29

Woodward [25] found that under Montana conditions cultivated plots of alfalfa yielded slightly more hay per acre than uncultivated plots, but that the increases probably were not sufficient to pay for the cost of cultivation.

A 3-year report from the Kansas Station [26] in 1908 reports 9922 pounds of hay per acre from disked plots and 10,269 from plots which were not disked.

In Nebraska Holden [27] reports a slight decrease from disking alfalfa, while cultivation with the spring tooth harrow resulted in a slight increase.

The Illinois Station [28] has continued cultivation experiments with alfalfa through a series of years using several different types of cultivators. This station does not advise cultivating. The plots not cultivated gave the highest total yield.

Nearly all stations in the region where blue grass does best have been recommending the cultivation of alfalfa as a means of controlling the grass and weeds of various kinds. At the Iowa Station alfalfa, which had been cultivated during the last 3 years of the period either with a spring tooth cultivator or with a disk, was producing excellent crops at the end of 8 years, when intervening alfalfa, not cultivated, was almost entirely crowded out by blue grass. There may be a good deal of question about the advisability of cultivating alfalfa as a regular practice.

The widespread appearance of alfalfa wilt in recent years and the serious losses occasioned by it will probably have an important influence on alfalfa cultivation as many believe that this disease is spread rapidly by such a practice.

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[25] Woodward, N. F.—"Experiments with Alfalfa and Grasses." *Mont. Agr. Expt. Sta. Bul. 152.* 1923.

[26] Ten Eyck, A. M.—"Alfalfa." *Kans. Agr. Expt. Sta. Bul. 155*, p. 210. 1908

[27] U. S. Dept. Agr.—"Western Irrigation Agriculture." *Bur. Plant Indus. Circ. 27*, p. 14. 1918.

[28] *Ill. Agr. Expt. Sta. Ann. Rpt. 37*, p. 33. 1925.

307. Cultivation of Soybeans. The Iowa Station[29] reports the yields of soybean seed for a 7-year period and yields of hay for a 4-year period, when cultivated and when not cultivated. The beans were drilled solid in a slightly sandy, black loam soil at the rate of 2 bushels per acre.

307a. Effect of cultivation on the yield of soybeans drilled solid. Iowa.

TREATMENT	YIELD PER ACRE	
	Seed: Bu.	Hay: Tons
No cultivation	20.7	1.9
Harrowed, 3 times	23.4	2.1
Weeder, 3 times	25.6	2.1

The beans were cultivated first when less than 1 inch in height, also when 3 and 6 inches in height.

Wolfe[30] reports cultivation comparisons with soybeans in Virginia as reported in Table *307b*.

307b. Effect of harrowing and cultivating soybeans. Virginia.

METHOD OF SEEDING AND CULTURAL TREATMENT	2-YR. AV. YIELD OF HAY IN TONS PER ACRE
Broadcast, no cultivation	2.90
Broadcast, harrowed when plants were breaking through the ground	3.68
Broadcast, harrowed when plants were 3 in. tall	3.28
In rows, no cultivation	2.35
In rows, 1 cultivation	3.50
In rows, 2 cultivations	3.50
In rows, 3 cultivations	4.18
In rows, harrowed when plants were breaking through ground and 2 cultivations later	3.07
In rows, harrowed when plants were 3 in. tall and 2 cultivations later	3.32

308. Cultivation of Pastures. Carrier and Oakley[31] of the Virginia station report an experiment in which different cultural treatments on blue grass pasture of 12 years' standing were compared. Comparative yields were secured by clipping, drying, and weighing the grass at intervals from these plots.

[29] Hughes, H. D., and Wilkins, F. S.—"Soybeans for Iowa." *Iowa Agr. Expt. Sta. Bul. 228.* 1925.

[30] Wolfe, T. K.—"Soybean Culture." *Va. Agr. Expt. Sta. Bul. 235.* 1924.

[31] Carrier, Lyman, and Oakley, R. A.—"The Management of Bluegrass Pastures." *Va. Agr. Expt. Sta. Bul. 204.* 1914.

Three cultural treatments were compared as indicated in Table *308a.* The disk was set so as to cut clean lines 2 or 3 inches deep and not turn or tear the sod to any appreciable extent. The harrow used was the ordinary "A" shaped, spike-tooth harrow.

308a. Cultural treatments for bluegrass pasture. Virginia.

TREATMENT	4-YEAR YIELD BLUEGRASS PER ACRE, LBS.
Disked	4764
Untreated	5747
Harrowed	5710
Disked and harrowed	5350
Untreated	6304

The Iowa Station reports[32] that disking old blue grass pasture during the years 1921, 1922, and 1923 has resulted in an increase in yield of grass each year though the increase has not been large. When reseeding and fertilization was practiced in conjunction with the disking, greater increases were obtained. Yields during the first 2 years were obtained by cutting frequently with a lawn mower and in the third year cutting twice during the season as for hay. The yields in tons of air-dry hay per acre in 1923 were: no treatment, 1.19; disked, 1.39; disked and reseeded, 2.26. The authors point out the need for giving the cultivation early in the spring and not too deep. The value of disking appears to be largely a matter of giving the new seed a favorable environment for growth.

309. Cultivation of Garden Soils. The Ohio Station reports[33] an interesting comparison of cultural methods on garden soils. One garden plot was cultivated weekly with a one-horse, 7-tooth cultivator to a depth of 2 or 3 inches; on a second the weeds were kept down by merely scraping the surface without forming a mulch, while on the third plot the surface was covered or mulched with straw to a depth of about 6 inches, this covering later settling down to a fairly compact layer 2 to 3 inches in depth. Tomatoes, sweet corn, cabbage, and beans were grown on these plots through a 3-year period. As an average for 2 out of the 3 years, the scraped plot yielded 22 per cent higher in the case of sweet corn and 15 per cent higher in the case of cabbage than the cultivated plots; while the mulched plots yielded 24 per cent higher for tomatoes, 35 per cent higher for sweet corn, 22 per cent higher for cabbage, and 10 per cent higher for lima beans than the cultivated plots. The mulched plots gave the largest total yield for the period. The scraped plot was second and the cultivated plot was lowest. In an unusually wet, cool year, 1924, the cultivated plots gave the largest yield, the scraped plots second, and the mulched plots lowest; as the rainfall was excessive and the soil under the mulch was too wet for proper plant growth.

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[32] Stevenson, W. H., Forman, L. W., and Brown, P. E.—"The Pasture Problem in Iowa." *Iowa Agr. Expt. Sta. Circ. 89.* 1924.

[33] Williams, C. G.—"Forty-fourth Annual Report of the Ohio Agricultural Experiment Station for the Year Ended June 30, 1925." *Ohio Agr. Expt. Sta. Bul. 392.* 1926.

The Effect of Cultivation on Soil Moisture

In order to understand the results obtained in tests of methods of cultivation it is necessary to study the effect that cultivation has on the various growth factors, particularly moisture, soil temperature, and soil nitrates.

Kinds of moisture and their distribution and movement have been explained. A large portion of the experimental work done in studying the effect of different methods of cultivation on the moisture of the soil has been done in the laboratory. **(151 to 163.)**

310. Early Studies with Dust Mulch. Wisconsin. King[34] studied the effect of mulches on the evaporation of water from the surface of the soil. He placed soil in cylinders which were approximately 4 inches in diameter and 20 inches in height. These were open at the top and closed at the bottom except for openings which permitted the free entrance of water. This apparatus was used to determine the amount of water lost from the soil by measuring accurately the water taken up by the soil from the bottom in a definite interval. King tested mulches of different depths and their effect on the water loss by evaporation from these containers. He used 3 types of soil and determined the water loss from each after a 100-day interval with no surface mulch, and with a 1-inch, a 2-inch, a 3-inch and a 4-inch mulch. His results, of far-reaching effects in influencing recommendations on cultivation, are given in Table *310a*.

In another test King[35] found that by cutting or slicing the soil vertically to a depth of 2 inches without disturbing it or moving it sideways, evaporation was increased from 0.75 of a pound daily to 1.38 pounds daily; and when this 2-inch layer was moved and thrown back loosely, it diminished the loss from evaporation to 0.5 of a pound daily.

The above results furnished the first, or the most important, basis for the so-called "dust mulch theory" with reference to cultivation. This theory calls for frequent cultivation in order to maintain a loose

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[34] King, F. H.—*Physics of Agriculture*, p. 186. Sixth edition. 1914. Mrs. F. H. King. Madison, Wis.

[35] King, F. H.—*The Soil*, p. 193. The Macmillan Co., New York City, N. Y. 1895.

310a. Water loss in 100 days with soil mulches of varying depths: Wisconsin. (King).

	No Mulch	1 In. Mulch	2 In. Mulch	3 In. Mulch	4 In. Mulch
Black marsh soil					
Tons water lost per A.........	588	355	270	256	253
Inches of water lost...........	5.2	3.1	2.4	2.3	2.2
Per cent saved by mulch......	....	39.5	54.1	56.4	57.1
Sandy loam					
Tons water lost per A.........	742	374	339	288	315
Inches of water lost...........	6.5	3.3	3.0	2.5	2.8
Per cent saved by mulch......	....	49.7	54.2	61.2	57.5
Virgin clay loam					
Tons water lost per A.........	2414	1260	980	889	884
Inches of water lost...........	21.3	11.1	8.7	7.9	7.8
Per cent saved by mulch......	....	47.8	59.4	63.1	63.3

layer of soil on the surface with the idea of preventing the loss of water by evaporation from the surface. (See chapter on Water.)

311. The Dust Mulch in Field Studies. Call and Sewell[36] studied the effect on the per cent of soil moisture in the field of mulching 3 inches and 6 inches as compared with no cultivation. Mulches were made by cultivating the surface. Three-year average results are shown in Table *311a.*

311a. Gain or loss of moisture under weeds, mulches, and bare surface, expressed in per cent + or —.

	Rainfall Jan. to Sept. Inches	Weeds Growing per Cent	3 In. Mulch per Cent	6 In. Mulch per Cent	Bare Surface per Cent
1914	17.93	— 7.28	— 3.31	— 1.86	— 0.89
1915	44.97	— 1.2	+ 0.70	— 0.05	— 0.70
1916	29.89	— 6.65	— 2.39	— 1.19	— 2.50
Average		— 5.05	— 1.66	— 1.03	— 1.36

On account of the run-off of water being more on one plot than another these investigators diked a similar set of plots to prevent run-off. In this series the plot where weeds were allowed to grow showed a loss of 3.65 per cent in soil moisture, the 3-inch mulch a gain of 0.30 per cent, the 6-inch mulch a gain of 2.37 per cent, and the bare surface a gain of 2.88 per cent.

Studies at the Nebraska station[37] show the moisture content of the soil under mulch and with no mulch,—the weed growth with no mulch being prevented by scraping.

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[36] Call, L. E., and Sewell, M. C.—"The Soil Mulch." *Jour. Amer. Soc. Agron.* Vol. 9, No. 2, pp. 49-61. Feb. 1917.

[37] Young, H. J.—"Soil Mulch." *Nebr. Agr. Expt. Sta. Ann. Rpt. 25*, pp. 125-127. 1911.

311b. Effect of mulching on per cent of soil moisture. Nebraska.

TREATMENT	MOISTURE CONTENT OF SOIL—PER CENT			
	1910		1911	
	June	Sept.	June	Sept.
Cultivated and hoed to keep mulch 2 in. deep........	27	27.4	24.7	25.1
Surface scraped, no mulch....	27.2	27.5	27.5	24.0
Weeds allowed to grow	26.1	25.5	26.8	18.3

It is stated that a hard layer of soil 2 to 3 inches deep developed on the surface of the scraped plot.

The yield of kafir corn in Oklahoma [38] cultivated in different ways to different depths and at different times has been reported in Table *302a*. The effect of the different cultivation practices on the per cent of soil moisture is shown in Table *311c*.

311c. Effect of mulching by cultivating to different depths and varying frequency on the per cent of soil moisture; kafir corn. Oklahoma. Seven-year average (1916-1922).

CULTIVATION	MOISTURE CONTENT OF SOIL IN PER CENT ON DIFFERENT DATES			
	May 29 June 15	June 26 July 5	July 11 July 20	July 25 Aug. 8
None—weeds allowed to grow.......	19.4	16.2	14.5	11.5
Weeds scraped off with a hoe.......	21.1	18.6	17.0	13.7
Deep after rains	19.9	19.1	18.2	15.4
Shallow 3 times	19.3	18.9	17.9	15.3
Shallow 5 times	19.1	18.1	17.9	15.0
Shallow after rains	19.5	18.1	17.8	14.7
Deep 3 times	19.3	18.7	17.4	14.6
Deep 5 times	19.0	17.8	18.5	15.3

The variation in forage yields should be taken into account. An additional pound of kafir forage produced means approximately 250 pounds of water removed from the soil through the plant.

At the Nephi Station, Utah,[39] winter wheat grown on a heavy soil which crusted badly was cultivated with a harrow in the spring to conserve moisture. The soil moisture content was determined at intervals throughout the season. The average in the spring for 3 cultivated plots was 18.4, 14.7, and 12.8 per cent and for the uncultivated plots, 19.0, 14.9, and 12.7 per cent, respectively. The wheat averaged 16 bushels for cultivated plots and 17 bushels for the uncultivated plots.

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[38] Murphy, H. F.—"Cultural Methods for Corn and Grain Sorghums on Oklahoma Soils." *Okla. Agr. Expt. Sta. Bul. 150.* 1925.

[39] Cardon, P. V.—"Tillage and Rotation Experiments at Nephi, Utah." *U. S. Dept. Agr. Dept. Bul. 157.* 1915.

The effect of rolling on the soil moisture content was determined in Wisconsin.[40] In 62 trials with moisture samples taken to a depth of 18 inches the rolled plats were found to contain an average of 15.85 per cent of water while those unrolled had 15.64 per cent. In 61 comparisons, sampling to a depth of 24 inches, the average of the rolled plats was 19.49 per cent while the unrolled was 19.85 per cent. In 24 comparisons sampling to a depth of 54 inches, the average of the rolled ground was 18.72 per cent water and the unrolled 19.43 per cent.

Thompson and Barrows state[41] that besides requiring larger amounts of water to maintain a given percentage of soil moisture, plots cultivated after irrigation showed smaller average yields and smaller yields per acre inch of water than was the case for plots which received no cultivation.

Grantham and McCool[42] compared the effect on the moisture content of the soil of clipping the weeds off at the surface without stirring the soil and cultivating the soil 3 inches deep with potatoes and with corn growing on the land. As a 3-year average when corn was the crop grown, scraping the surface gave a moisture content of 6.09 per cent and where the land was cultivated 3 inches deep the moisture content was 6.48 per cent. When potatoes was the crop grown, the moisture contents were practically reversed; 6.47 per cent moisture when the surface was scraped and 6.02 per cent when cultivated 3 inches deep.

At the Arkansas Experiment Station[43] the moisture content was determined on plots receiving different cultural treatments. The water content of plots given medium shallow cultivation till the corn was tasseled was the standard with which plots receiving other cultural treatments were compared. When the weeds were allowed to grow, there was a loss of 39 tons of water per acre above that of the standard plots. Where the weeds were scraped, there was a loss of 8 tons; where the cultivation was about 1 inch deep till tasseled, the loss was 3 tons; where the cultivation was deep till tasseled there was a gain of 3 tons; where the cultivation was medium shallow until the corn was 2 feet high, there was a loss of 12 tons.

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[40] King, F. H.—*Physics of Agriculture*, p. 186. Sixth edition. 1914. Mrs. F. H. King. Madison, Wis.

[41] Thompson, C. A., and Barrows, E. L.—"Soil Moisture Movement in Relation to Growth of Alfalfa." *N. Mex. Agr. Expt. Sta. Bul. 123.* 1920.

[42] Grantham, G. M., and McCool, M. M.—"Determinations of Soil Moisture." *Mich. Agr. Expt. Sta. Quart. Bul.* Vol. 2, No. 3, p. 142. 1920.

[43] Sachs, Ward H.—"Effect of Cultivation on Moisture and Nitrate Content of Field Soil." *Ark. Agr. Expt. Sta. Bul. 205.* 1926.

312. The Theory of Soil Mulches. Soil moisture, except in the case of saturated soil, is in the form of a film around the soil particles (151). The force of cohesion or the attraction of water molecules for each other forms these films into a smooth, spherical shape, just as is the case with a drop of water. When two soil particles, each with its film, are brought into contact the water in contact joins and the surface tension of the water film tends to pull out around the two, forming one sphere. If these 2 soil particles differ in the moisture content of their films; that is, if one has a thick and one a thin film of water around it, the angle made by the water film at the junction of the 2 particles will be sharper in the case of the drier soil. The attraction for water; that is, the pull of water toward a soil particle with a thin film will be stronger than it will be toward those where there is a greater quantity of water. The tendency in all soils is to bring about an equilibrium in the attraction between soil particles. The theory of the soil mulch, in preventing or checking the evaporation of soil moisture, is that through loosening the surface by cultivation, the soil particles are removed from intimate contact with one another, making a smaller number of contacts to lift the water; also, the surface particles lose most of their water by evaporation and as water does not move readily into a dry soil the movement of the water is thus retarded.

Shaw[44] has studied soil moisture relations in California and finds that a soil has a normal moisture capacity which represents the minimum amount of water that is retained by absorption and film forces when the water is free to move downward through a mass of uniform soil; for medium textured soil this is approximately the same as the moisture equivalent. The moisture at normal moisture capacity is readily available to plants but is not free to move under normal film forces. It is essentially static. In this condition mulches are of little or no effect in conserving soil moisture as upward movement to supply evaporation does not occur. Rain and irrigation soon bring a uniform soil to normal moisture capacity.

313. Paper and Straw Mulches. Harris and Turpin[45] found that certain mulches were effective in preventing a loss of moisture under both irrigation and dry farming conditions. The surface foot showed the greatest benefit from the mulches though the increase was apparent for several feet below the surface. The straw mulch proved considerably better than the soil mulch. The soil mulch held only slightly more moisture than the plot with no mulch at all.

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[44] Shaw, C. F.—"The Normal Moisture Capacity of Soils." *Soil Sci.* Vol. 23, No. 4, p. 317. 1927.

[45] Harris, F. S., and Turpin, H. W.—"Movement and Distribution of Moisture in the Soil." *Jour. Agr. Res.* Vol. 10. No. 3, pp. 113-152. July 16, 1917.

In a comparison at the California station,[46] of paper mulches with holes in them (perforated) and non-perforated papers, it was found that the non-perforated paper mulch retained slightly more moisture in the upper 3 feet than the perforated paper, the soil mulch, or the bare earth. The differences in moisture content and in soil temperature were slight between those plots mulched with paper and those left bare.

THE EFFECT OF CULTIVATION ON SOIL TEMPERATURE

314. Early Studies by King. The effect on the soil temperature of cultivating 1.5 inches deep in comparison with 3 inches deep was studied by King.[47] The temperatures were obtained by drilling a hole to the desired depth, placing the thermometer in it, plugging up the hole for 15 minutes, and then reading.

314a. The effect of the depth of cultivation on soil temperature. King. Wisconsin.

CULTIVATION	TEMPERATURE TAKEN AT DEPTHS OF			
	1 Ft.	2 Ft.	3 Ft.	4 Ft.
1½ in. cultivation	72.85°F.	70.88°F.	68.93°F.	65.94°F.
3 in. cultivation	72.45	70.22	67.80	64.81
Difference	.4	.66	1.13	1.13

King[48] reports the effect of rolling spring plowed land on the soil temperature. The soil temperature was read between 1 and 4 P. M. and at 1.5 inches and 3 inches below the surface of the soil. The mean air temperature was 79.7° F.; the temperature of the rolled ground 1½ inches deep was 89.89° and the unrolled, 86.12°. The temperature of the rolled ground 3 inches deep was 81.49° and the unrolled, 76.47°.

315. Other Field Studies on Soil Temperature. Oskamp[49] reports the effect of various tillage methods on the temperature of the soil. The temperature of 3 plots under the treatments shown below was determined at weekly periods throughout the year. Only selected weeks are reported in Table *315a*.

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[46] *Calif. Agr. Expt. Sta. Ann. Rpt.* 1925-26, pp. 83-84.

[47] King, F. H.—"Studies Relating to Ground Water and Soil Moisture." *Wisc. Agr. Expt. Sta. Ann. Rpt. 10*, p. 192. 1892-93.

[48] King, F. H.—"Some Effects Produced by Rolling Ground." *Wisc. Agr. Expt. Sta. Ann. Rpt. 7*, p. 122. 1888-89.

[49] Oskamp, Joseph—"Soil Temperatures as Influenced by Cultural Methods." *Jour. Agr. Res.* Vol. 5, No. 4, p. 173. Oct. 25, 1915.

315a. Temperature of soil on different dates, as influenced by cultivation, mulch and sod.

WEEK ENDING	PLOT A		PLOT B		PLOT C	
	Cultivated; Rye Used as Cover Crop Previous Fall		Grass Cut and Let Lay; Straw Mulch Added		Timothy Sod	
	Min.	Max.	Min.	Max.	Min.	Max.
May 5	45.0	58.5	47.0	53.0	44.5	57.5
May 12	53.0	60.0	50.0	53.0	48.5	59.0
May 19	53.0	63.0	50.0	56.0	49.0	62.0
May 26	54.0	63.0	55.0	57.0	53.0	62.5
June 9	60.0	69.0	58.5	61.5	58.0	67.0
July 7	73.0	80.5	68.0	71.0	70.0	78.5
Sept. 1	66.0	73.0	66.0	69.0	62.5	68.5
Oct. 6	55.0	63.0	58.0	61.0	52.5	59.5
Feb. 2	34.0	46.5	37.0	41.5	35.0	44.0

Illinois reports[50] the general relation between seedbed preparation, cultivation, and temperature in Table *315b*.

315b. Temperature of the soil as influenced by methods of cultivation. Illinois.

PREPARATION OF SEEDBED	CULTIVATION	DEPTH TESTED	MEAN ANNUAL TEMP. FAHR.		
			9:00 A.M.	1:45 P.M.	4:45 P.M.
Not plowed	Weeds scraped	2 in.	74.3	88.0	86.1
Plowed	Cult. shallow three times	2 in.	72.6	83.3	82.2
Not plowed	Weeds scraped	4 in.	71.7	82.3	82.9
Plowed	Cult. shallow three times	4 in.	70.4	80.1	81.1

Temperatures averaged higher in the spring on the plowed land and in the summer on the unplowed land. (172, 173)

316. The Effect of Paper Mulches on Temperature. Shaw[51] found that covering the soil with an asphalt coated paper hastened the time of warming, retarded the rate of cooling, and gave a narrower range between the maximum and minimum temperatures, thereby resulting in more uniform temperature conditions. The covered plots were warmer than plots not covered 62.5 per cent of the time and the two were about equal 9 per cent of the time.

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[50] Mosier, J. G., and Gustafson, A. F.—"Soil Moisture and Tillage for Corn." *Ill. Agr. Expt. Sta. Bul. 181.* 1915.

[51] Shaw, Charles F.—"The Effect of a Paper Mulch on Soil Temperatures." *Hilgardia.* Vol. 1, No. 15, p. 363. April, 1926.

At Davis, California,[52] covering with black, non-perforated paper resulted in a temperature 3 inches below the surface which averaged 4.7° higher during the day and 5.3° higher during the night, than when the soil was not covered but was cultivated. At a one-half inch depth the paper mulch caused the day temperature to be 7.1° warmer and the night temperature 7.9° cooler than the bare plots.

THE EFFECT OF CULTIVATION ON NITRATES IN THE SOIL

317. Cultivation and Soil Nitrates. Call and Sewell [53] studied the effect of weed growth, 3-inch mulch, 6-inch mulch, and a bare surface on the development of nitrates under Kansas conditions in 1914, 1915, and 1916. The 1914 season was one of comparatively light rainfall,—17.93 inches from January 1 to October 1,—evenly distributed. The 1915 season was one of heavy precipitation, 44.97 inches falling during the same period. This came principally in the months of May, June, and July. In 1916, the precipitation from January 1 to October 1 was 29.89 inches with July and August very dry. The annual and average nitrate content of the soil in pounds per acre for the upper 3 feet on the plots given different cultural treatments were as shown in Table *317a*.

317a. The effect of season and cultural methods on the pounds of nitrates per acre in the upper three feet of soil. Kansas.

YEAR	TREATMENT			
	Weeds	3-Inch Mulch	6-Inch Mulch	Bare Surface
1914	124.3	497.8	550.1	712.7
1915	42.1	495.9	325.2	643.0
1916	78.5	246.3	567.8	313.3
Average	81.6	413.3	481.0	556.3

Lyon [54] studied the aëration of soil and its effect on the nitrates from data gathered at the Cornell Station. For 2 years, comparisons were made between cultivation, scraping the surface, and mulching with straw. The cultivated plot showed consistently the highest nitrate content with the scraped plots intermediate and the mulched plots lowest. The mulched plots yielded the highest; the cultivated, second; and the scraped plots, slightly lower.

Lyon also reports the effect of aëration on a compact soil with

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[52] *Calif. Agr. Expt. Sta. Ann. Rpt. 1925*, p. 84.

[53] Call, L. E., and Sewell, M. C.—"The Soil Mulch." *Jour. Amer. Soc. Agron.* Vol. 9, No. 2, pp. 58-60. Feb. 1917.

[54] Lyon, T. L.—"Intertillage of Crops and Formation of Nitrates in the Soil." *Jour. Amer. Soc. Agron.* Vol. 14, No. 4, pp. 106-107. 1922.

37.5 per cent of air space. The nitrate content without aëration in parts per million of dry soil was 4.2 on November 7 and a trace on January 5; when aërated, 15.4 and 28.9, respectively. The nitrate content of a less compact soil with 42.1 per cent air space, without aëration, on November 7, was 4.2 and on January 5 9.7; when aërated the nitrogen content was 17.6 and 26.0, respectively.

Albrecht[55] studied the effect of tillage and of straw mulches on soil nitrates. He found that the amount of nitrates in an untilled soil, under sod, was closely correlated with the rainfall distribution through the year. Ordinary shallow surface cultivation increased the amount of nitrates in the surface soil, but excessive cultivation lessened it. Straw mulches had a decidedly depressing effect on nitrate formation. He found that fall plowing in July or August had a distinct influence on nitrate accumulation. Significant nitrate increases followed plowing for wheat with greatest increases occurring in the soil plowed in July.

Arkansas cultivation tests[56] give information on the effect of various cultural methods on the nitrate content of the soil under fallow and under crops. The nitrate content of the plots receiving "medium shallow tillage until tasseled" is used as a basis and the nitrate content of soils receiving other treatments shown as plus or minus. There can be no question regarding the effect of cultivation on the nitrate content of soils, whether with a growing crop or without.

317b. The effect of cultural methods on the nitrate content of the soil, with and without a growing crop; nitrate content expressed in pounds per acre, plus or minus standard treatment plot. Arkansas.

METHOD OF CULTIVATION	SEASONAL AVERAGE Nitrate Nitrogen Lbs. per Acre	
	Fallow	Cropped
Scraped with hoe	9	1
Very shallow until tasseled	—4	—1
Medium shallow until tasseled	0	0
Medium deep until tasseled	3	1
Deep until tasseled	2	—2
Medium shallow until 2 ft. high	—1	—3
No cultivation	—21	—6

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[55] Albrecht, W. A.—"Nitrate Accumulation in Soil as Influenced by Tillage and Straw Mulch." *Jour. Amer. Soc. Agron.* Vol. 18, No. 10, p. 853. Oct., 1926.

[56] Sachs, Ward H.—"Effect of Cultivation on Moisture and Nitrate Content of Field Soil." *Ark. Agr. Expt. Sta. Bul. 205.* 1926.

STUDY QUESTIONS ON CHAPTER XI

1. List the different reasons for cultivating corn, arranging in order of importance.
2. What effect did fertilizers and irrigating have on the relative yields of crops as reported by the Illinois Station with (a) weeds growing, (b) weeds scraped, and (c) shovel cultivation? Explain.
3. Can you locate, geographically, a section in which cultivation gave a significant increase over weed removal only? Under what conditions might one expect this?
4. What determines the number of times that corn should be cultivated? What advice would you give with regard to late cultivation between the rows?
5. How deep should corn be cultivated? From your study of the roots of a plant and of soil fertility, explain the data on depth of cultivation.
6. What advantages, if any, has the harrow over other implements for the early cultivation of corn?
7. Summarize, for your state: data on alfalfa cultivation, wheat cultivation, soybean cultivation, and pasture cultivation.

APPLICATION ASSIGNMENTS ON CHAPTER XI

1. A field of corn has been cultivated twice, the second time three weeks ago. In another week, it will be too large to cultivate again. The field is level and no weeds are coming. Will you cultivate? Why?
2. Immediately after the third cultivation of a fairly clean field a beating rain packed the soil. Will you cultivate? Why?
3. A weedy field, cultivated four times and too large for all except one-horse cultivation, is becoming very weedy after a rain. Will you cultivate? Why?
4. A level field, free of weeds, has been packed by rains since the last cultivation three weeks ago. Will you cultivate to hold the moisture? Why?
5. Your field of corn is grassy but has no large weeds. How deep will you cultivate it? Why?
6. Your corn is still small and has only grass in it but you know that before you can cultivate again, the roots of the plant will be extending out so that a deep cultivation will cut them off. How deep will you cultivate? Why?
7. You are to talk to a farm gathering on "Past and present views on the movement of soil moisture and its conservation by cultivation." Write your speech.
8. Would you apply the same rules with reference to garden cultivation as to field cultivation? Why?
9. What is the basis for the belief that cultivation holds water in the soil?
10. What effect does cultivation have on rain absorption? On evaporation from the surface? Explain.

11. What happens, with reference to moisture, to a soil stirred early in the spring?
12. What effect have the following on moisture: rolling, packing, cultivating, weeds?
13. Summarize the results with reference to moisture control, from the use of a mulch in comparison with no mulch but with the soil surface not crusted.
14. How does a mulch of paper or straw differ from a soil mulch in its effects on moisture?
15. In general, what is the effect of cultivation on the temperature of the soil in the spring? In summer? Why?
16. What is the effect of cultivation on soil nitrates?

CHAPTER XII

SEED

Nutrition and reproduction are the two great functions of plants. The production of seed is the principal means by which field plants increase in number and the means by which annual plants live over from year to year or even through adverse seasons when no new seed are produced.

318. What Is a Seed? The seed consists of a plant embryo and stored food material surrounded by a seed coat. Seed may vary greatly in size, shape, and color as well as in the internal structure. Those of the cereal plants and grass forages consist of the embryo or germ, the endosperm, and the seed coat. The seed of the legume plants contain no endosperm, the bulk of the seed being made up of the two cotyledons, which, in these plants, constitute the food storage portion. The embryo is found between and at one edge of the two cotyledons. Each part of the seed has distinct functions to perform. The embryo is made up of the plumule, radical, and scutellum. The plumule develops into the above ground portion of the plant and also into the permanent root system, while the radical forms the temporary roots. The seed coat is very essential in protecting the embryo and endosperm during the resting stage of the seed. In the process of germination the scutellum, which is that part of the embryo next to the endosperm or stored food material, serves to dissolve this stored food through the secretion of enzymes and assists in the transfer of such food to the plumule and radical. Most seed after they complete their development dry out and pass into a stage of dormancy. This dormant period is known as the resting stage, the duration of which varies greatly with different seed, ranging from a few days to months or even years. In this resting stage life processes are reduced to a minimum but do not actually stop. Seed in the resting stage have remarkable endurance and can survive, without injury, conditions which would kill them were they active.

319. Several Kinds of Dormancy. There are several different kinds of dormancy in seed. Some seeds are dormant because the embryos are not capable of immediate germination when given the ordinary germinating conditions. It would seem that the embryos of certain seeds, at least, must go through a series of chemical changes before growth can start.

In a second type of dormancy, the seeds have embryos which are capable of immediate germination but the rest period is forced upon the embryo through certain structures which prevent proper conditions for germination. This form of rest period is usually enforced by the seed coat. The seed coat may inhibit or restrict water absorption, or in certain cases keep out oxygen. The germination of many of our field crop seeds is affected by the inhibiting character of the seed coat.

Seed of most grain must be stored for at least a few weeks after harvest to give good germination at the temperatures ordinarily used in germination tests. The very low germination of timothy seed soon after harvest is an example of the extent to which dormancy may be a factor in determining seed viability.

320. Dormancy in Small Grain. Whitcomb[1] found that the general belief of seed analysts that grains have a dormant period following threshing was borne out by laboratory tests with wheat, oats, and barley when tested at a constant temperature, but that good stands could be obtained in the field by the planting of newly threshed grain. He found that by exposing these grains between the folds of moist blotting paper at a rather low temperature in an ice chest for 6 days prior to the regular germination test the vitality could be determined accurately. The results obtained in this way were comparable to field results.

Whitcomb[2] tested the germination of newly harvested grain in several ways with results given in Table *320a.*

320a. Germination of newly threshed grain. Montana.

CONDITIONS FOR GERMINATION	WHEAT	SPRING WHEAT	OATS	BARLEY
	Per Cent			
Germinated between blotters 20°C.	27.4	51.0	48.1	70.8
Germinated in soil 20°C.	27.2	49.4	51.5	70.3
In box with alternating 20° and 30°C.	90.6	90.0	85.1	96.0

Harrington[3] has shown that the rest period following the harvest of wheat can be abbreviated in a number of ways,—by running the germinator at 15° C. instead of at 20°; by breaking the seed coat over the embryo; by cutting off the brush end of the grain, or by eating away a portion of the seed coat with sulphuric acid.

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[1] Whitcomb, W. O.—"Germination of Newly Threshed Grain." *Assoc. Off. Seed Anal. North America. Proc. 14-15,* p. 84. 1923.

[2] Whitcomb, W. O.—"A Study of Methods in Making Germination Tests." *Assoc. Off. Seed Anal. North America. Proc.* 14-15, p. 68. 1923.

[3] Harrington, George T.—"Forcing the Germination of Freshly Harvested Wheat and Other Cereals." *Jour. Agr. Res.* Vol. 23, No. 2, pp. 79-100. Jan. 13, 1923.

Crocker[4] states that in Germany the term "rain barley" is used in referring to barley that ripens during rainy weather and that such barley is reported to have a longer rest period than barley ripened during dry weather. Rain barley delays the malting operations and is a source of considerable annoyance.

Dormancy in Miscellaneous Seed. Toole and Goss[5] state that a number of different kinds of seed are more or less dormant under certain conditions. The dormancy is shown by the fact that the seed, though swollen, remain unsprouted at the expiration of the time normally required for germination. They have noticed varying degrees of dormancy occurring at times in Canada bluegrass, Johnson grass, Bermuda grass, white clover, alsike clover, hairy vetch, soybeans, lettuce, mustard, collards, wheat, and oats. Also, that while germinating certain of these seed at 20° C. or less usually overcomes the dormancy, Canada bluegrass, Johnson grass, and Bermuda grass each require an alternation of the temperature with a fairly wide range,—20 to 25° C. for Johnson and Bermuda grass and 20 to 30° C. for bluegrass. In making transfer from one of these temperatures to the other the transfer should be abrupt. This dormancy should not be confused with the dormancy due to "hard seed" in legumes.

321. Hard Seed. Seed of many plants, particularly certain legumes, have an enforced resting period generally attributed to an impervious seed coat which prevents the penetration of water. Harrington[6] terms "hard seed" impermeable seed, and states that with the exception of peanuts they are found in all legumes that are grown commercially in the United States. They are also present in many other cultivated plants. He states[7] that in nature nine-tenths or more of well-matured seeds of alsike clover, red clover, white clover, and sweet clover are hard. The fact that in nature a very large per cent of the seed of the clovers are hard while commercial seed of the same species may show a relatively small per cent of such seed is attributed to the scarifying effect of clover hulling machinery or to especially devised scarifying equipment.

Harrington found that 38 samples of red clover seed from one huller had 10 per cent of the seed hard, while 16 samples from another huller in the same community and hulled at the same time, showed 22 per cent of hard seed. The difference was apparently due entirely to differences in the adjustment of the two hullers.

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[4] Crocker, Wm.—"Points of Agronomic Interest in the Physiology of Germination." *Jour. Amer. Soc. Agron.* Vol. 17, No. 11, p. 699. Nov., 1925.

[5] Toole, E. H., and Goss, W. L.—"The Analysts' Interest in Dormancy Problems." *Assoc. Off. Seed Anal. North America. Proc.* 14-15, p. 90. 1923.

[6] Harrington, George T.—"Agricultural Value of Impermeable Seed." *Jour. Agr. Res.* Vol. 6, No. 20, pp. 761-796. Aug. 14, 1916.

[7] Harrington, George T.—"Hard Clover Seed and Its Treatment in Hulling." *U. S. Dept. Agr. Farmers' Bul. 676.* 1915.

Sweet clover has a harder or more impervious seed coat than red clover or alfalfa and is not so easily scarified in ordinary hulling machinery. Only a few years ago the commercial sweet clover seed on the market showed a notoriously high per cent of hard seed. With the introduction of special scarifying machinery almost all sweet clover seed handled by seedsmen is scarified so that at present the average commercial lot of this clover has a percentage of hard seed but little, if any, higher than is found in other clovers.

Hughes [8] found that for samples of clover seed submitted by Iowa farmers from January 1, 1926, to September 1, 1926, the per cent of hard seed was as shown in Table *321a*.

321a. Germination and hard seed of clover samples. Iowa.

CROP	NO. SAMPLES	PER CENT GERMINATION	PER CENT HARD	PER CENT DEAD
Red clover	624	84.58	9.50	6.13
Alfalfa	417	79.95	16.56	7.65
Alsike clover	170	80.05	13.72	6.22
Sweet clover	444	78.08	15.00	7.45

The sweet clover seed handled by many seedsmen will show a lower per cent of hard seed than is found in red clover or alfalfa seed handled by the same firms, due to the fact that most sweet clover is scarified while the others are not.

322. The Why of Hard Seed. The "hard seed" character found in legume seed represents an adaptation in nature to insure the perpetuation of these plants. For example, red clover seed ripening in the late summer, if capable of absorbing moisture, with the first rain, would germinate while still in the flower head only to shrivel and die in a few days.

Sweet clover, notable for its hard seed, matures in August and September, the seed falling to the ground. If these seed could absorb moisture they would germinate with the first rain, only to be killed when freezing weather came on. Under natural conditions it is only after the freezing weather of winter that any considerable per cent of these seed are able to germinate.

The hard seed character seems to develop in legume seed during the final stages of maturity or as the seed dries, since many legume seed will give an almost perfect germination if tested before they have been allowed to dry thoroughly but which, when once thoroughly dry, will be found to be almost altogether hard.

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[8] Hughes, H. D.—*Unpublished Data. Ia. Agr. Expt. Sta.* 1926.

Martin,[9] working at the Iowa Station after long study, concluded that impermeability of the seed coat to water is due to the "light line,"—a layer of cells situated near the inner surface of the seed coat.

Nelson,[10] working with sweet peas and other legumes, found evidence for the belief that hardness is a result of a varnish-like deposition on the seed surface, within and by the pod. He states that hard seed occurs in practically every sample and that the best ripened seed contains the most hard seed.

323. Duration of Hard Character in Legume Seed. Harrington[11] states that impermeable seed frequently retain their vitality for many years, sometimes as many as 80 years. Hard seed, or impermeable seed which are still impermeable at the end of 3 to 5 years under laboratory conditions of storage, have retained their vitality apparently unimpaired for that time. Red clover seed become permeable gradually in dry storage, but from one-third to two-thirds of them still may be impermeable after 4 years. The majority of impermeable seed of alfalfa and hairy vetch become permeable before they are 2 years old. Impermeable clover seed which were thoroughly mature before harvest, become permeable in dry storage more slowly than those which were not thoroughly matured.

Harrington kept hard seeds of various kinds between moist blotters and observed the rate at which they became permeable. He found 8 per cent of the hard seed of red clover softened in 1 month, 30 per cent in 1 year, 44 per cent in two years and 55 per cent in 3 years. With sweet clover, 5 per cent sprouted in 1 month, 27 per cent in 1 year, 35 per cent in 2 years and 44 per cent in 3 years. With alfalfa, 46 per cent softened in 1 month and practically all of them in 1 year.

Lute[12] observed that one-half of the impermeable alfalfa seed became permeable in 3½ years in storage and all in 11 years.

Relative germinations in the field, in the greenhouse, and between blotters were observed by Whitcomb[13] with reference to hard seed of alfalfa and sweet clover. Between blotters, alfalfa seed germinated

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[9] Martin, J. N.—"The Structure and Development of the Seed and the Cause of Delayed Germination in Melilotus Alba." *Iowa Acad. Sci. Proc.* Vol. 29, p. 345. 1922.

[10] Nelson, Alexander—"Hard Seeds in Leguminosae." *Nature* [London] 118, pp. 804-805. Dec. 4, 1926.

[11] Harrington, George T.—"Agricultural Value of Impermeable Seed." *Jour. Agr. Res.* Vol. 6, No. 20, p. 794. Aug. 14, 1916.

[12] Lute, Anna M.—"Impermeable Seed of Alfalfa." *Colo. Agr. Expt. Sta. Bul. 326.* 1928.

[13] Whitcomb, W. O.—"The Germination of Hard Seed of Alfalfa and Sweet Clover as the Season Advances." *Assoc. Off. Seed Anal. North America. Proc 17*, pp. 31-32. 1925.

11.1 per cent in one-half week and in 24 weeks 56.6 per cent; under greenhouse conditions one week, 12.6 per cent germinated and in 24 weeks 65.9 per cent; under field conditions, in 2 weeks 49.7 per cent and in 24 weeks 83.7 per cent. Sweet clover between blotters germinated 1.1 per cent in one-half week and 4.7 per cent in 24 weeks; in the greenhouse, 1.2 per cent germinated in 1 week and 3.7 per cent in 24 weeks; in the field, 1.3 per cent in 2 weeks and 3.3 per cent in 24 weeks.

324. Effect of Freezing on Hard Seed. Hughes and Norton[14] found at the Iowa Station that clover seed subjected to normal temperature fluctuations of an Iowa winter showed a considerable decrease in the per cent of hard seed, while the same lots of seed carried through the winter at temperatures above freezing showed little change.

The effect of freezing has been tested by a number of workers. Harrington[15] found that freezing dry seed had little effect on the permeability of the seed. He states that under field conditions freezing increases the permeability of seed but may kill some seed which were previously soft. He found also that after the first freezing, subsequent freezing and thawing had only a small effect upon the hard seed content. It is likely that alternate freezing and thawing renders many seed permeable and may kill many of these seed by subsequent freezing.

Schmidt[16] reports that when seedings were made in the fall and winter or very early spring with consequent exposure to freezing and thawing for some time, hard seed of alfalfa produced very few plants, sweet clover 40 to 45 per cent, and red clover, white clover, and alsike 15 to 20 per cent. When sown just after the frost has left the soil, most of the hard seed of alfalfa will germinate, while only 10 to 15 per cent of those of red clover, white clover, alsike, and sweet clover will germinate during the first season. When sown in late spring or midsummer the germination of hard seeds is very low. It is evident that the kind of seed, the per cent of hard seed, and the time of seeding are factors which should be considered jointly.

325. Scarification of Hard Seed. It has been found that scratching the seed coat of hard seed or pricking with a pin or chipping in any way makes it possible for the seed to germinate promptly. Sulphuric acid also has been used to eat away portions of the seed coat, thus permitting the entrance of water. Scratching or chipping the seed coat is usually referred to as scarification.

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[14] *Unpublished data. Iowa Agr. Expt. Sta.*

[15] Harrington, George T.—"Agricultural Value of Impermeable Seed." *Jour. Agr. Res.* Vol. 6, No. 20, pp. 761-796. Aug. 14, 1916.

[16] Schmidt, Z.—"The Hard Seed Problem to Date." *Assoc. Off. Seed Anal. North America. Proc.* 18, p. 42. 1926.

Scarifying machines. A machine designed by H. D. Hughes and E. S. Scales of the Iowa station was first made available in 1913 and rapidly came into general use by seedsmen, as well as by many seed growers, for scarifying sweet clover seed. The essential features of this machine are a blower and an angular or circular spout lined with sandpaper or some similar abrasive. The seed are carried by an air blast through the angular spout and into contact with the sandpaper, this action resulting in hulling and scarifying. Since 1920 a number of different scarifying machines have appeared on the market.

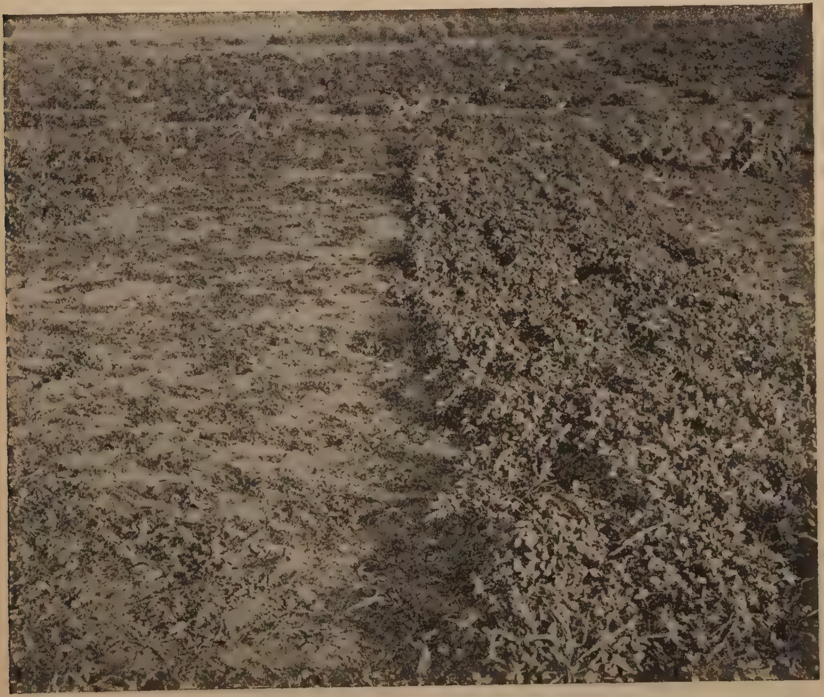

FIG. 72.—The results of scarifying sweet clover seed. The plot on the left was planted with unscarified sweet clover seed; the one on the right with the same seed after scarification. *What is "scarification" and under what conditions is it advisable?*

Graber [17] reports sweet clover which germinated 28 per cent, with 60 per cent of hard seed, after scarifying germinated 80 per cent with 5 per cent of hard seed.

Scarifying increased the germination of sweet clover seed from 51 per cent to 92 per cent and reduced the hard seed from 44 to 5 per

[17] Graber, L. F.—"Scarification as It Affects Longevity of Alfalfa Seed." *Jour. Amer. Soc. Agron.* Vol. 14, No. 8, p. 299. Nov., 1922.

cent at the Crookston station, Minnesota; 1.12 per cent of the seeds were broken.[18]

At the Iowa station 15 samples of Hubam clover were increased from an average of 28 per cent germination to 87 per cent germination by scarifying.

The chipping and cracking of the seed allows more or less free entrance of air with resultant drying and more rapid oxidation. This is in agreement with the notable longevity of hand hulled legume seed, most of which are hard. Graber[19] concludes that where legume seed is to be stored for over one year it is best to delay scarification until a short time before using. Work at a number of stations has indicated that scarified seed does not retain its vitality as well as unscarified seed.

326. Dormancy in Weed Seed. It is a well known fact that the seed of many weeds will live over in the soil for a long period of years. In most cases this is due to an impervious seed coat though in others dormancy is induced in other ways.

Oswald[20] found at the Maryland station that while the great majority of weed seed fed to animals was destroyed, enough remained viable to be a factor in weed distribution. When manure was hauled directly from the stable as a top dressing, an average of 12.8 per cent of the weed seed fed germinated. Where manure was hauled directly from the stable and plowed under, 2.3 per cent of the weed seed fed to animals came up. Where the droppings remained on the pasture fields as they fell, an average of 3.1 per cent of the seed fed to the animals germinated. They conclude that when the manure is allowed to remain in piles and undergo partial fermentation, little danger of distributing weeds is incurred, and, when the manure is allowed to ferment in piles 6 months, all seed are killed. (See also Chap. 37.)

GERMINATION OF SEED

The necessary conditions for seed germination are: a viable seed, moisture, oxygen, and proper temperature.

327. Germination and Moisture. In most cases the germination of seed is controlled by controlling the amount of moisture available to it. The chief factor considered in seed storage is moisture, since it is much more difficult to control temperatures and oxygen than moisture.

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[18] Selvig, C. G.—"Report of Northwest Experiment Station, Crookston, 1923." *Minn. Univ. Dept. Agr. Bul. Crookston Series.* Vol. 17, No. 1, p. 57. Jan., 1924.

[19] Graber, L. F.—"Scarification as it Affects Longevity of Alfalfa Seed." *Jour. Amer. Soc. Agron.* Vol. 14, No. 8, pp. 298-302. Nov., 1922.

[20] Oswald, Edward Ingram—"The Effect of Animal Digestion and Fermentation of Manures on the Vitality of Seeds." *Md. Agr. Expt. Sta. Bul. 128.* 1908.

The water absorbed by the seed saturates the cell walls and starch grains and fills the living cells of the embryo and all empty spaces that exist in the seed. Most seed swell with the absorption of water, sometimes more than doubling their size. This absorption of water is the first step in germination. Accompanying this, there is an increase in the enzymes in the seed which digest the food, changing the starch into substances with greater solubility and the ability to move about in solution. Coupled with this is the process of respiration which supplies energy for the elaboration of the food into plant structure and which is accompanied by the absorption of oxygen and the production of carbon dioxide, water vapor, and some heat. The final step in the germination process is the breaking of the seed covering, and the establishment of the plumule and radical of the young plant in the soil and sunlight. (220)

328. Oxygen Necessary in Germination. Air contains sufficient oxygen for the germination of most seed, although in certain cases germination may be hastened by supplying additional oxygen artificially. Seed planted too deep, where the soil is packed by rain, may germinate poorly from want of oxygen. Germination is likely to be poor where the soil contains an excessive amount of water, thereby excluding air.

329. Temperature with Reference to Germination. The temperature at which certain seed barely germinate, germinate best, and the highest temperature at which they will germinate are known as minimum, optimum and maximum. Martin[21] reports these temperatures for a number of seed as shown in Table *329a*.

329a. Minimum, optimum and maximum temperatures for germination.

KIND OF SEED	MINIMUM DEGREES F.	OPTIMUM DEGREES F.	MAXIMUM DEGREES F.
Oats	32-41	77-88	88-99
Wheat, rye	32-41	77-88	88-108
Corn	41-51	99-111	111-122
Red clover	32-41	77-88	99-112
Peas	32-41	77-88	88-98
Sunflowers	41-51	93-111	111-122
Pumpkins	51-61	93-111	111-122
Cucumber	60-65	88-89	111-122

Abbe[22] hollowed out a cavity in a cake of ice in which he placed certain seed, covered it with another cake, and surrounded the whole with 2 feet of ice. At the end of 2 months, rye, wheat, cabbage, beans, and mustard were germinating and the roots penetrating the ice cake.

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[21] Martin, John N.—*Botany with Agricultural Applications.* John Wiley and Sons. New York. 1924.

[22] Abbe, Cleveland—*U. S. Dept. Agr. Weather Bur. Bul. 36.* 1905.

Coffman[23] states that different species germinate very differently under different temperatures. Within a species starchy seeds seem to be unable to resist low temperatures as well as the more oil seeds. He states that all small grain will germinate at a temperature of melting ice. Under these conditions the strength of germination seems to be in the following order: barley, rye, wheat, and oats. The seed of alfalfa and the clovers germinate more readily at low temperatures than the seed of other commonly grown crops.

330. Heating and Drying of Seed and Germination. Harrington[24] found that the per cent of germination was not materially changed when wheat, barley, sudan grass, Kentucky bluegrass, and Johnson grass were dried to less than one per cent of moisture.

Ewart[25] dried seed of wheat, corn, barley, peas, beans, hemp, squash, rape, and sunflower and concluded that it was possible to reduce the percentage of water held by even resistant seed to lower than 2 or 3 per cent of their dry weight without affecting their vitality.

Jones[26] states that the exposure of dry rice seed at 150° F. for one hour did not affect the germination, but at 170° F. the germination of one variety was reduced, and at 205° F. all seed were killed.

Alberts and Flint[27] report that the kiln drying of immature corn at 112° F. resulted in injury to the seed as indicated by the lower germination. Corn which had over 15 per cent of moisture was injured by exposing it to a temperature of 125° F. for three hours. This treatment has been found to be effective in killing insects in all stages of development. The vitality of corn which contained from 2 to 15 per cent of moisture was not injured by the above treatment.

331. Storage and Germination. Immature seed sown soon after harvest germinate readily but if stored they soon lose their vitality. The most important factors determining the vitality of a seed are maturity, weather conditions at the time of harvesting, methods of harvesting, and curing and storage conditions.

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[23] Coffman, F. A.—"The Minimum Temperature of Germination of Seeds." *Jour. Amer. Soc. Agron.* Vol. 15, No. 7, pp. 257-270, July, 1923.

[24] Harrington, George T., and Crocker, William—"Resistance of Seeds to Desiccation." *Jour. Agr. Res.* Vol. 14, No. 12, p. 532. Sept. 16, 1918.

[25] Ewart, A. J.—"Additional Observations on the Vitality and Germination of Seeds." *Liverpool Biol. Soc. Trans. and Proc.* Vol. 10, pp. 185-193. 1895 and 1896.

[26] Jones, Jenkin W.—"Germination of Rice Seed as Affected by Temperature, Fungicides, and Age." *Jour. Amer. Soc. Agron.* Vol. 18, No. 7, p. 591. July, 1926.

[27] Alberts, H. W., and Flint, W. P.—"The Effect upon the Vitality of Seed Corn of Temperatures Which Will Kill Seed Infesting Insects." *Jour. Econ. Ent.* Vol. 18, No. 6. 1925.

Moisture is the chief factor affecting the longevity of seed as they are commercially handled. Seed stored under low humidity conditions retain their vitality much longer than when stored in places with a humid atmosphere.

332. Longevity of Seed. The conditions of storage have a very great influence on the length of time that seed will retain their vitality. Seed held in storage under very favorable conditions,—dry air, uniform temperature, and perhaps with the exclusion or partial exclusion of oxygen,—may retain their vitality through a long period of years, but when kept under average farm conditions are unsafe to plant after 2, 3, or 5 years.

Ewart [28] reports the germination of a sample of white sweet clover 44 years old as 52 per cent and another sample of the same species 77 years old as 18.2 per cent. He concluded that the seed which retain their germinating power for the longest time are legumes. This has a very practical application.

Becquerel [29] tested over 500 species of seeds ranging from 25 to 135 years old. Seed of a legume, *Cassia bicapsularis*, germinated after 85 years of storage.

Seed of the lotus over 200 years old are reported as germinating 100 per cent by Ohga.[30] These seed have lain in a layer of peat in a drained lake bed for several centuries and are still giving 100 per cent germination with greater vigor of seedlings than is shown by one-year-

332a. Viability of various forage seed stored in paper bags in a dry airy room during eleven years.

KIND OF SEED	PERCENTAGE OF VITALITY										
	1 Yr.	2 Yr.	3 Yr.	4 Yr.	5 Yr.	6 Yr.	7 Yr.	8 Yr.	9 Yr.	10 Yr.	11 Yr.
Red clover	90	90	88	84	74	68	44	16	10	3	2
White clover	74	72	63	52	50	50	35	31	26	23	22
Alsike clover	73	64	51	37	15	7	6	5	3	3	3
Serradella	36	32	33	22	14	11	9	6	2	0	0
Alfalfa	94	91	87	75	72	71	68	66	63	59	54
Tall oat-grass	70	66	59	43	24	12	10	2	1	0	0
Timothy	95	90	90	88	86	79	66	39	15	1	0
Orchard grass	46	47	44	44	39	29	21	12	8	5	0
Bluegrass	28	17	17	17	16	11	8	5	2	0	0
Sheep fescue	68	67	68	42	21	18	10	4	3	0	0

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[28] Ewart, A. J.—"Longevity of Seed." *Proc. Roy. Soc. Victoria.* Vol. 21, Part 1, p. 210. 1908 and 1909.

[29] Becquerel, P.—"Recherches sur la vie latente des graines." *Ann. Sci. Nat. Bot.* 9: 193-311. 1907. (From review, Darsie, M. L., Elliott, C., and Peirse, Geo. J.—"A Study of the Germinating Power of Seeds." *Bot. Gaz.* Vol. 58, p. 102. 1914.)

[30] Ohga, I.—"On the Longevity of Seed of *Nelumbo nucifera* (lotus)." *Bot. Mag.*, Tokyo. Vol. 37, pp. 439-444. 1923.

332b. Germination of various seed, and the hard seed content of certain of the legumes, after storage at ordinary room temperatures for different periods of time.

CROP	YEARS OF STORAGE												
	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	15th	20th	27th
Red clover	97 + 3	99 + 1	97 + 3	86 + 5	48 + 4	8 + 2	2 + 2	0 + 2	0 + 1	0 + 3	0	0	0
White Dutch clover	86 + 15	77 + 22	80 + 10	79 + 12	71 + 16	48 + 13	23 + 8	16 + 10	12 + 9	8 + 10	1 + 7	0 + 10	0 + 8
Alsike clover	83 + 16	81 + 18	83 + 15	77 + 19	53 + 17	17 + 16	9 + 14	5 + 14	4 + 16	1 + 14	7 + 6	1 + 7	0
Alfalfa	91 + 8	88 + 7	93 + 3	84 + 3	79 + 3	65 + 3	61 + 2	53 + 2	37 + 5	34 + 4	4 + 0	0	0
Crimson clover	98 + 0	95 + 1	90 + 0	41 + 0	10 + 0	1 + 0	0	0	0	0	0	0	0
Timothy	98	95	91	79	53	12	4	1	0	..	..	..	..
Perennial rye grass	92	89	89	87	67	41	24	10	3	0.3	..	..	..
Italian rye grass	83	79	79	65	57	40	22	15	6	2	..	..	..
Meadow fescue	98	94	96	81	42	6	0	..	..	..	..	..	..
Oats	84	71	81	75	59	58	56	54	47	32	0	0	0
Orchard grass	90	85	88	88	77	71	59	27	16	1	0	..	..
Red top	91	96	93	92	92	91	80	50	44	32	0	..	..
Bluegrass	78	94	87	85	72	44	32	12	10	1	..	..	..
Barley	100	100	97	90	42	5	0	..	..	..	..	..	..
Wheat	92	95	87	88	74	78	24	3	0	..	..	..	..
Rye	93	88	65	20	3	0	..	..	..	..	..	..	..
Beet	84	90	88	86	92	76	72	67	65	53	0	0	0
Rape	98	97	98	95	98	94	92	84	79	66	0	0	..
White mustard	96	96	95	91	92	87	90	85	85	76	9	..	..
Flax	72	69	68	50	38	31	13	12	5	6	1	0	0

old seed. These seed have about 9 per cent moisture and are buried about 3 feet below the surface.

Samek[31] stored seed in small quantities under favorable conditions. The viability or germination for yearly periods is given in Table *332a* on p. 281.

Seed of a number of different crop plants were stored at the Danish state seed testing station[32] at the usual room temperature of 18° C. Each year 300 seeds of each species were tested for germination with the results shown in Table *332b* (p. 282).

Sometimes it is necessary to fall back on old seed corn for planting purposes. Hayes and Olson[33] report a 3-year comparison in Table *332c*.

332c. Age of seed corn and yield. Minnesota.

Variety of Corn	Yield in Bushels per Acre					
	1916		1917		1918	
	1 Yr. Old	2 Yr. Old	1 Yr. Old	2 Yr. Old	1 Yr. Old	2 Yr. Old
Minn. 23	37.9	40.1	20.7	20.2	....	...
Chowens Y. D...	41.5	37.4	20.9	18.9	....	....
Silver King	40.7	42.6	22.5	19.8	44.8	51.9
Mercer	....	....	23.6	21.6	43.5	44.5
Murdock	....	....	15.8	15.7	46.3	50.1

333. Buried Seed and Germination. Goss[34] buried the seed of 107 species of plants in 1902. A portion of these seeds were dug up in 1903, '05, '08, '12, '18, and '23. Of these 107 species, 71 grew in 1903, 61 in 1905, 68 in 1908, 69 in 1912, 50 in 1918, after 16 years, and 51 in 1923 after 20 years. He states that the seed of most weeds, when plowed under, will not be killed during the period of any normal crop rotation. His conclusion does not invalidate the importance of plowing weeds under before the seed has matured. Cultivated plants seem to depend very largely upon human agencies for their perpetuation. The following plants failed to grow in any of the tests after a burial of one year at either 8 inches, 22 inches, or 42 inches: corn, oats, wheat, rye, barley, onions, asparagus, hemp, buckwheat, beans, peas, cowpeas, flax, cotton, pepper, watermelon, cucumber, lettuce, and cultivated sunflowers. Some of the seed of the following crops were still viable at the end of 20 years: timothy, Kentucky bluegrass, ramie, sugar beets, alsike clover, red clover, white clover, celery, and tobacco. Among the seed of common weeds 36 different kinds showed viability in 1923, 20 years after burying. (See also Chap. 37.)

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[31] Samek, J. "Duration of the Vitality of Some Agricultural Seeds." *Tirol Landw. Blatter 13.* No. 18, pp. 161-162. 1894.

[32] Dorph-Petersen, K.—"How Long Do the Various Seed Species Retain Their Germination Power?" *Internatl. Rev. Sci. and Pract. Agr. (Rome).* New series, Vol. 2, pp. 284-285. 1924.

[33] Hayes, H. K., and Olson, P. J.—"First Generation Crosses between Standard Minnesota Corn Varieties." *Minn. Agr. Expt. Sta. Bul. 183.* 1919.

[34] Goss, W. L.—"The Vitality of Buried Seeds." *Jour. Agr. Res.* Vol. 29, No. 7, pp. 349-362. Oct. 1, 1924.

334. Size of Seed. Kiesselbach,[35] at the Nebraska station, has made a very thorough study, under practical field conditions, of the influence of size of small grain seed on yield. He compared hand selected large and small seed, representing extreme grades of winter wheat, spring wheat, and oats. Small seed yielded 18 per cent less than the large when spaced to permit maximum individual plant development. Small seed yielded 10 per cent less when equal numbers of seed were sown per acre at an optimum rate for the larger seed, and 5 per cent less when equal weights of seed were sown per acre at an optimum rate for the larger seed. Unselected seed yielded 4 per cent less than large seed when equal numbers were sown per acre and one per cent less when equal weights were sown.

Winter wheat was graded with a fanning mill during a 17-year period. The heaviest one-fourth produced 0.3 per cent more than the unselected seed. The lightest one-fourth yielded 2 per cent less than the unselected. The heaviest one-fourth of Kherson oats yielded 0.9 per cent more and the lightest one-fourth yielded 0.7 per cent less than the unselected seed.

Zavitz [36] has compared the effect of the size of the seed of the different small grains on the yield of grain and of straw. These separations do not represent the effect of fanning. The seed were uniformly spaced in planting so that the same number of seed were planted in a given area of ground. These data are presented in Table 335.

Schmidt,[37] reporting studies which included soybeans, buckwheat, lima beans, and corn, found that seed of high medium weight produced better plants than either seed of lighter weight or abnormally heavy seed.

336. Adulteration of Seed. The adulteration and misbranding of seed was much more prevalent a few years ago than at present. Reputable seedsmen are doing all that they can to bring about the general adoption of higher business standards while the enactment of federal and state seed legislation has also had an important influence. Adulteration and misbranding are more likely to be found in the

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[35] Kiesselbach, T. A.—"Relation of Seed Size to the Yield of Small Grain Crops." *Jour. Amer. Soc. Agron.* Vol. 16, No. 10, p. 680. Oct., 1924.

[36] Zavitz, C. A.—"Forty Years' Experiments with Grain Crops." *Ontario, Canada, Dept. Agr. Bul. 332.* 1927.

[37] Schmidt, David—"The Effect of the Weight of the Seed on the Growth of the Plant." *N. J. Agr. Expt. Sta. Bul. 404.* 1924.

335. Size of Seed of Small Grain as Affecting Yield. Zavitz, Canada.

Selections	Class of Grain	Years the Tests Have Been Repeated	Weight per Measured Bu.	Average Yield per Acre per Annum	
				Straw (Tons)	Grain (Bushels by Weight)
Large seed	Oats	7	33.2	1.9	62.0
Medium sized seed	Oats	7	32.2	1.8	54.1
Small seed	Oats	7	31.8	1.8	46.6
Large plump seed	Barley	6	49.5	1.5	53.8
Small plump seed	Barley	6	48.8	1.5	50.4
Shrunken seed	Barley	6	49.1	1.4	46.0
Broken seed	Barley	6	48.6	1.3	43.2
Large plump seed	Spring wheat	8	59.1	1.4	21.7
Small plump seed	Spring wheat	8	58.3	1.3	18.0
Shrunken seed	Spring wheat	8	56.9	1.2	16.7
Large plump seed	Winter wheat	6	59.4	2.6	46.9
Small plump seed	Winter wheat	6	59.2	2.2	40.4
Shrunken seed	Winter wheat	6	59.1	2.1	39.1
Split seed	Winter wheat	6	54.2	.6	9.3
Large seed	Peas	6	56.3	1.3	28.1
Small seed	Peas	6	56.3	1.1	23.0
Sound seed	Peas	9	58.1	1.4	29.2
Split seed	Peas	9	57.9	.6	10.2
Large seed	Spring rye	6	53.3	2.0	26.0
Medium sized seed	Spring rye	6	53.3	2.0	24.4
Small seed	Spring rye	6	53.5	1.9	22.3
Broken seed	Spring rye	6	52.8	1.6	16.9

smaller seeded forage crops than in the small grains or corn. Cheap seed has been used to dilute the higher priced seed of similar appearance, or has been substituted entirely. Trefoil may be sold for alfalfa, Canada blue for Kentucky blue grass, medium red for mammoth red clover, biennial white sweet clover for Hubam, common alfalfa for Grimm or other hardy varieties, and Italian rye grass for meadow fescue. Misbranding of this type is difficult to detect. Forage crop seed may be foul with dangerous and noxious weed seed without the average purchaser detecting their presence.

337. The Federal Seed Act. For many years the United States was the dumping ground for low grade, foul, and adulterated seed from other countries. With the passage of the Federal Seed Act this has all been changed. Brown,[38] in charge of the Federal Seed Laboratory, summarizes this act as follows:

"The title under which the seed importation act, as amended, is now known, gives the American farmer a greater measure of protection with respect to imported forage plant seeds than he is given with respect to the same seeds of domestic production. All seeds subject to the act meet the following requirements before they are permitted entry to the United States: (1) contain not to exceed 5 per cent of adulterants; (2) contain not to exceed 3 per cent of weed seed; (3) contain not to exceed 90 seeds per pound of dodder in the case of clover and alfalfa; (4) contain not less than 65 per cent of live seed of the kind,—in the case of bluegrass, 50 per cent; (5) seed of red clover and alfalfa will be colored to indicate origin, as follows: Seed declared by the Department of Agriculture to be unadapted to general use in the United States and seed of unknown origin will be colored 10 per cent red; seed from Canada, one per cent violet; seed from all other sources, one per cent green; (6) seed shipped from one state to another will be subject to seizure and confiscation if willfully misbranded."

After thorough investigation by a number of experiment stations in coöperation with the United States Department of Agriculture, alfalfa from Turkestan, Africa, Italy, and South America has been declared unadapted to general use in the United States and must be stained 10 per cent red to be allowed entry. Red clover from Italy has been declared generally unadapted and must be stained 10 per cent red. The original act was passed in 1912 and amended in 1916, while the seed-staining regulations of the act became effective in 1926.

338. The Uniform Seed Law. Because of the great variety of seed laws in different states the Association of Official Seed Analysts of North America gave considerable effort to the formulation of a practical and effective seed law which it approved in 1917 and recommended to the different states for general adoption. Many states now have seed laws based on this "Uniform State Seed Law."

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[38] Brown, Edgar.—"Seed Import Control Law Strengthened." *U. S. Dept. Agr. Yearbook*, p. 647. 1926.

Most of the state seed laws require the labeling of all crop seed offered for sale in the state, showing the commonly accepted name of the seed, the per cent of pure seed and of weed seed, the name of noxious weeds when present in excess of certain minimum numbers, the per cent germination and date of germination test, and the name and address of the vendor of such seed. Mixtures must also show the name and approximate per cent by weight of the different crop seed present.

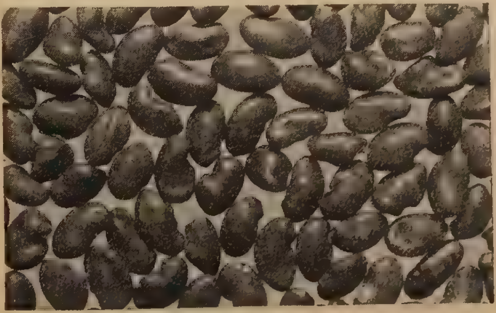

FIG. 73.—A sample of high grade alfalfa seed, plump and free from weeds and trash. *Can the variety or source be determined from an examination of the seed? How can a grower who wants Grimm seed be sure of getting it? How can he be sure of the source of common alfalfa seed?*

339. Noxious Weeds. Weeds named as noxious in the seed laws of different states are as listed in Table *339a*, p. 288. The number of states in which a particular weed has been so named suggests the relative extent to which it has been found troublesome.

Other weeds, each listed as noxious in some one state, are as follows: Sweet clover, king devil, burr clover, blue devil, burdock, tumbling mustard, Indian mustard, cowbane, poison hemlock, poison sumac, poison ivy, prickly lettuce, velvet weed, broom rape, August flower, shepherd's purse, blue weed, fanweed, Russian knapweed, marsh elder, Russian pigweed, purslane, holy grass, wild barley, poverty weed, hoary cress, creeping mallow, St. John's wort, water grass, ground burr nut, red rice, careless weed, lamb's quarter, burr grass, hop clover. (See also Chap. 37.)

340. Seedsmen's Disclaimer. A disclaimer which has been adopted by the American Seed Trade Association and is used almost universally by seedsmen,—even the most reputable and honorable,—is as follows: "The (John Brown) company gives no warranty, expressed or implied, as to the description, quality, productiveness or any other matter of any seed they send out and will not be in any way responsible for the crop." This disclaimer is presented on letter heads, in seed catalogs, and on tags attached to the seed itself.

339a. Weeds listed as noxious in the seed laws of two or more states.

COMMON NAME	SCIENTIFIC NAME	NUMBER OF STATES LISTING AS NOXIOUS
Dodders	*Cuscuta sp.*	32
Canada thistle	*Cirsium arvense*	26
Quack grass	*Agropyron repens*	25
Wild mustard	*Brassica arvensis*	16
Buckhorn plantain	*Plantàgo lanceolata*	16
Corn cockle	*Agrostemma githago*	16
Wild oats	*Avena fatua*	15
Wild onion	*Allium canadense*	14
Bindweed	*Convolvulus sp.*	11
Per. sow thistle	*Sonchus arvensis*	10
Curled dock	*Rumex crispus*	10
Russian thistle	*Salsola kali*	8
Wild carrots	*Dancus carota*	8
Sheep sorrel	*Rumex acetosella*	7
Orange hawk weed	*Hiracium aurantiacum*	7
Johnson grass	*Holcus halepensis*	7
Plantain	*Plantago sp.*	7
Mustard	*Brassica sp.*	5
Crab grass	*Syntherisma canquinalis*	5
Yellow trefoil	*Medicao lupulina*	4
Bermuda grass	*Capriola dactylon*	4
Chickweed	*Alsine media*	4
Florida nut grass	*Cyperus rotundus*	3
Horse nettle	*Solanum carolinense*	3
Oxeye daisy	*Chrysanthemum leucanthemum*	3
Chicory	*Cithorium intybus*	3
French weed	*Thlaspi arvense*	3
Dandelion	*Leontodon taraxacum*	3
Bracted plantain	*Plantago aristata*	2
Star thistle	*Centaurea solstitialis*	2
Butter and eggs	*Mallow rotundifolia*	2
White top	*Erigeron ramosus*	2
White mustard	*Brassica alba*	2
White cockle	*Lychnis alba*	2
Catchfly	*Silene noctiflora*	2
Wiregrass	*Elensine indica*	2
Cheat	*Bromus secalinus*	2
Corn flower	*Centaurea cojanus*	2

Wheeler [39] points out that no responsible grower or merchant has any intention of selling seed which are not true to name or of unmerchantable quality, but that the crop produced is out of the hands and jurisdiction of the seller, who has no opportunity to make a profit on it; and if it were not for the disclaimer the seller might be called on to reimburse the planter for large sums many times in excess of the value of the seed should the market returns not satisfy the planter.

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[39] Wheeler, Lynn W.—"Why the Disclaimer of Warranty." *Seed World.* Vol. 21, No. 12. June 17, 1927.

341. Seed Certification. New and improved strains and varieties of high yielding and adapted seed have been released by the various experiment stations, by the United States Department of Agriculture, and by others. Little work was done in this country to keep pure sources of these superior seed until in recent years, and as a result many of these strains have become badly mixed. For this reason seed certification and registration work has been undertaken in many states.

The certifying agency. Certification and registration are usually done by an independent organization or association of farmers which coöperates with the state college of agriculture,—in most cases the State Crop Improvement Association. This association may furnish its own inspectors, but usually the inspection is done by men in crops work connected with the state college. Several classes of seed may be recognized for certification by the association.

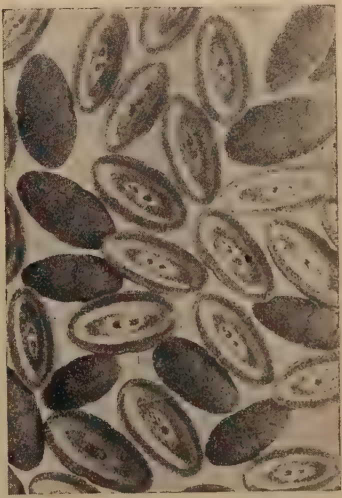
Fig. 74.—Seed of bracted plantain.

Élite seed usually is the highest grade of seed obtainable and must originate directly from a single plant, the progeny of which has been proven worthy of distribution in plot or field test under the supervision of experiment station workers.

Registered seed is seed which has come directly from registered seed or élite seed and which has met the requirements of registered seed. Considerations of purity of variety, vigor, freedom from disease, and germination, conditions of seed with reference to plumpness, soundness, color, and freedom from weed seed are usually taken into account. Registered seed must usually be completely free of noxious weed and other crop seed and not fall below its standard weight per bushel for the crop. This seed is high class seed and is relatively scarce.

Certified seed includes the bulk of improved seed for sale for commercial growing. The requirements for certified seed are slightly lower than for registered seed. Certified seed must be free from noxious weeds, sound, and of reasonably good color. Self-fertilized varieties, as for example most of the small grains, should be 99 per cent pure and weigh not less than 2 pounds below the bushel standard.

Inspected seed. Some associations carry in their seed lists a fourth class of seed called inspected seed, which is seed of relatively good quality but which for some reason failed to pass the certification requirements.

Requirements for certification and registration vary somewhat with the crop and with the state.

342. **Verified Seed Service.** Verified seed is seed the locality of production of which is assured to the buyer through a verified-origin certificate issued under authority of the United State Department of Agriculture. Seed is not verified as to purity, germination, variety, or quality but only as to locality of origin.

FIG. 75.—The weeds present in this seeding of grass are the result of purchasing low grade seed. *What protection is available to the purchaser of such seed?*

The seed verification service was inaugurated in the fall of 1927. Only those seed dealers who agree to keep such complete records and samples and allow such inspection as will make it possible for the Department to trace back to the point of production any particular lots of seed are granted this service. Alfalfa, clover, and corn are the only crops thus far considered and the crop seed to be included may vary from year to year.

343. **Standards of Quality in Seed.** Seed of the different farm crops vary greatly in the per cent of purity and of germination which

may be regarded as satisfactory for reasonably high grade seed. These differences are usually due to differences in the character of the seed itself, or in the methods which it is necessary to follow in harvesting and in curing. Rape seed and the seed of the cereals may be expected to show a purity of 99 per cent or better, while many of the more common of the small seeded legumes can be marketed with a purity of about 98 per cent. However, most of the smaller seeded grasses can but seldom be brought to a purity of more than 90 to 95 per cent. Even greater differences may be noted in the germination of the different seed. There is no reason why a good grade of seed of the cereals and of the larger seeded grasses should not germinate around 95 per cent, while an equally good grade of bluegrass may show a germination of less than 60 per cent. The smaller legume seed will often show a germination of not over 90 per cent because of the presence of "hard" seed. The average purity and germination tests of the best commercial grades of seed of several field crops have been reported as set forth in Table *343a.*

343a. Average purity and germination tests of best commercial grade of seed and commonly accepted weight per bushel.[a]

Kind of Seed	Purity per Cent	Germination per Cent	Weight per Bushel—Pounds
Lespedeza	93.9	82.1	25
Redtop	93.2	90.5	14[b]
Bermuda grass	91.5	77.9	35
Golden millet	98.8	92.9	50
Siberian millet	97.9	92.7	50
Hungarian millet	97.5	92.4	48 – 50
Broom-corn millet	99.3	92.1	50
Amber sorgo	97.9	88.2	50
Sudan grass	98.0	91.1	32
Kafir	98.1	91.3	50
Rape	99.2	91.8	50
Flax	98.5	87.3	56
Buckwheat	98.6	92.7	48 – 52

[a] *Seed Trade Buyers Guide* for 1927.

[b] Fancy recleaned, solid redtop seed weighs 30 to 38 pounds or more, per measured bushel.

Munn[40] indicates in Table 344 the standards for purity and germination generally recognized as satisfactory, the average number of seed per pound, and the number of years that the different seed may be expected, under average conditions, to retain their vitality to such an extent as to have value for planting.

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[40] Munn, M. T.—"Rules for Seed Testing." *N. Y.* [*Geneva*] *Agr. Expt. Sta. Circ.* 73. 1924.

344. Standards of Purity and Germination.

Kind of Seed	Longevity Average Years	U. S. Dept. of Agr. Standards		Wt.[a] per Bu.	No. of Seed per Lb.
		Purity	Germination		
Barley	3	99	90 – 95	48	15,786
Corn	4	99	90 – 95	56	1,440
Oats	3	99	90 – 95	32	12,700
Rye	2	99	90 – 95	54 – 56	29,250
Wheat	2 – 7	99	90 – 95	60	14,000
Alfalfa	6 – 8	98	85 – 90	60	219,500
Alsike clover	2	95	75 – 80	60	698,500
Crimson clover	2	98	85 – 90	60	149,600
Red clover	5 – 6	98	85 – 90	60	313,900
Sweet clover	5	99	85 – 90	60	259,400
White Dutch clover	2	95	75 – 80	60	785,200
Hairy vetch	3	98	70 – 75	60	16,300
Spring vetch	3	98	70 – 75	60	8,600
Bluegrass—Canada	1 – 2	90	45 – 50	14 – 50	2,512,900
Bluegrass—Kentucky	1 – 2	90	45 – 50	14 – 28	2,201,300
Brome, smooth	5	90	75 – 80	14	136,900
Meadow fescue	2	95	85 – 90	22 – 24	227,200
Meadow foxtail	..	..	......	7	908,100
Millet, common	4	98	85 – 90	48 – 50	220,900
Millet, Japanese	4	98	85 – 90	32 – 35	155,100
Orchard grass	2 – 3	97	90 – 95	14	586,500
Rape, Dwarf Essex	6	99	90 – 95	50	109,300
Redtop	6	95	90 – 95	14 – 38	5,084,500
Rye grass, Italian	2	98	90 – 95	24	275,300
Rye grass, Perennial	2	98	90 – 95	24	336,100
Sheep fescue	..	..	......	12	680,800
Tall oat grass	..	..	......	10	14,900
Timothy	5 – 6	98	85 – 90	45	1,230,100
Cotton, upland	..	99	85	32	4,220

[a] Weights per bushel are either standard for New York or those in common usage.

345. Standards for Official Germination Tests. It is a well recognized fact that different seed require somewhat different conditions of temperature and light for optimum germination; also that there are marked differences in the rapidity with which the different seed germinate. It is apparent that these differences must be recognized and the germination tests made accordingly if dependable results are to be secured. With seed laws in many of the different states, which require certain standards of germination and of purity, and with state laboratories checking the accuracy of labeling, it is important that certain standard methods of testing be recognized. After much experimentation in many seed laboratories the Association of Official Seed Analysts of North America has recommended that in making germination tests seed be subjected to the temperatures shown in Table 346 under the conditions noted for seedbed and duration.

346. Seedbed, Temperature, and Duration of Germination Tests.

KIND OF SEED	SEEDBED[a]	TEMPERATURE FAHRENHEIT	DAY FOR CHECKING GERMINATION TEST	
			Preliminary	Final
Field Crops				
Barley	B	68	3	5
Beans	C	68–75	3	6
Beets b–c	B	68–75	5	10
Buckwheat	B	68–75	3	5
Corn	C	68–75	3	5
Flax	TB	68–75	2	5
Hemp	B	68–75	3	5
Oats	B	68	3	5
Peas	C	68–75	4	8
Rye	B	68	3	5
Turnips	B	68	3	5
Wheat	B	68	3	5
Grasses, Clover, Forage Plants				
Alfalfa	B	68	3	5
Bermuda grass	BJ	68–75	10	21
Bluegrass	BJ	68–75	14	28
Brome grass	B	68–75	5	10
Clover, alsike	TB	68	3	5
Clover, crimson	B	68	2	4
Clover, mammoth red	B	68	3	5
Clover, common red	B	68	3	5
Clover, white	TB	68	3	5
Cowpeas	C	68–75	4	10
Johnson grass	B	68–75	6	10
Meadow fescue	B	68–75	5	10
Millet	B	68–75	3	5
Orchard grass	B	68–75	6	14
Rape	B	68	3	5
Redtop	TB	68–75	5	10
Sorghum	B	68–75	3	5
Sudan grass	B	68–75	3	5
Timothy	TB	68–75	5	8
Turnips	B	68	3	5
Vetch	C	68–75	4	14

[a] NOTE: B—Between blotting paper.
TB—On top of blotting paper with seeds in dark.
BJ—On top of blotting paper with seeds kept in light by covering germinating dish with plate of glass.
C—Between folds of cloth.

347. Value of Seed Crops. It is estimated that over $500,000,000 of seed is required annually to plant our fields and gardens. Forage crop and garden seed are to a very large extent produced by special seed growers in regions of the country which are particularly adapted to these crops and the handling of them for seed,—the product being handled through the regular channels of seed distribution.

Seed of all of the cereals is for the most part produced in the areas of production for market; probably 90 per cent is produced on the farms where planted. The local adaptation of varieties makes this almost imperative. Any good farmer, with a little care, can produce and handle seed of these crops as satisfactorily as special seed growers and dealers.

348. Seed-Producing Centers. Seed of hay and pasture crops is not ordinarily produced by the average grower but is produced in areas best suited to seed production. Large marketing agencies have come into these regions with special facilities for cleaning and marketing.

The production of redtop seed is confined almost entirely to southern Illinois, while northern Kentucky and southern Indiana produce the bulk of the orchard grass seed. By far the greater part of the Kentucky bluegrass seed is produced in the limited area in east central Kentucky, with smaller amounts coming from limited areas in Missouri and Iowa.

While red clover is grown very extensively in rotations throughout the whole corn belt, the production of seed of this crop is important only in limited areas in Michigan, Wisconsin, Minnesota, Ohio, Indiana, Illinois, Iowa, and Idaho. Production is increasing very rapidly in Idaho and new areas are also developing in Colorado.

349a. Normal

Group of States	Grasses			Clovers and Alfalfa		
	From Own Farm	From Other Farms	From Dealers	From Own Farm	From Other Farms	From Dealers
	%	%	%	%	%	%
Eastern	5	2	93	6	3	91
Southern	6	4	90	11	5	84
Central	23	12	65	30	18	52
Northern	69	13	18	18	16	66
Far Western	4	2	94	12	9	79

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[a] Oakley, R. A.—"The Seed Supply of the Nation." *U. S. Dept. Agr. Yearbook 1917*, p. 500 .

By far the greater part of the alfalfa seed is produced in areas where the production of this seed is made a specialty with very little grown for hay. Oakley [41] has prepared an outline map of the United States showing areas producing various kinds of crop seeds for market. It will be observed from this map (Fig. 76) that the great bulk of the seed of some of our important crop plants is produced in rather limited areas.

349. Source of Planted Crop Seed, by Groups of States. Edler of the Bureau of Markets of the United States Department of Agriculture reports a survey [42] to determine the source of different classes of seed planted on farms in different parts of the United States. Table *349a.*

350. When the Purchase of Crop Seed Is Justified. It is the general practice for farmers to purchase certain of their crop seed. Edler, after making a study of field seed marketing, suggests the following conditions which may make it more profitable for an individual farmer to purchase crop seed than to produce them.

"(1) His fields may be foul with noxious weeds; (2) soil, climatic, and other conditions on his farm may be unfavorable for seed production in a given year; (3) altitude, latitude, or rainfall in his locality may preclude production of a particular kind of seed in any year; (4) he may be able to buy better seeds at a lower cost than can be produced in his locality; (5) he may find it more profitable to grow a crop for hay or forage purposes than for seed production; (6) he may not have the facilities for harvesting, cleaning, curing, or otherwise preparing his seed for planting purposes; (7) he may need seed of a crop that has not been grown by him for several years, if ever; and (8) he may have to replant his fields either with the same kind of seed (his supply of which may have been exhausted with the first planting) or with seed of some catch crop."

sources of seed supply.

MILLETS			FORAGE SORGHUMS			SMALL GRAINS		
From Own Farm	From Other Farms	From Dealers	From Own Farm	From Other Farms	From Dealers	From Own Farm	From Other Farms	From Dealers
%	%	%	%	%	%	%	%	%
3	1	96	1	0	99	44	12	44
12	6	82	36	13	51	45	15	40
20	11	69	25	12	63	76	15	9
13	10	77	5	5	90	78	14	8
7	3	90	16	18	66	59	15	26

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[42] Edler, Geo. C.—"Seed Marketing Hints for the Farmer." *U. S. Dept. Agr. Farmers' Bul. 1232.*

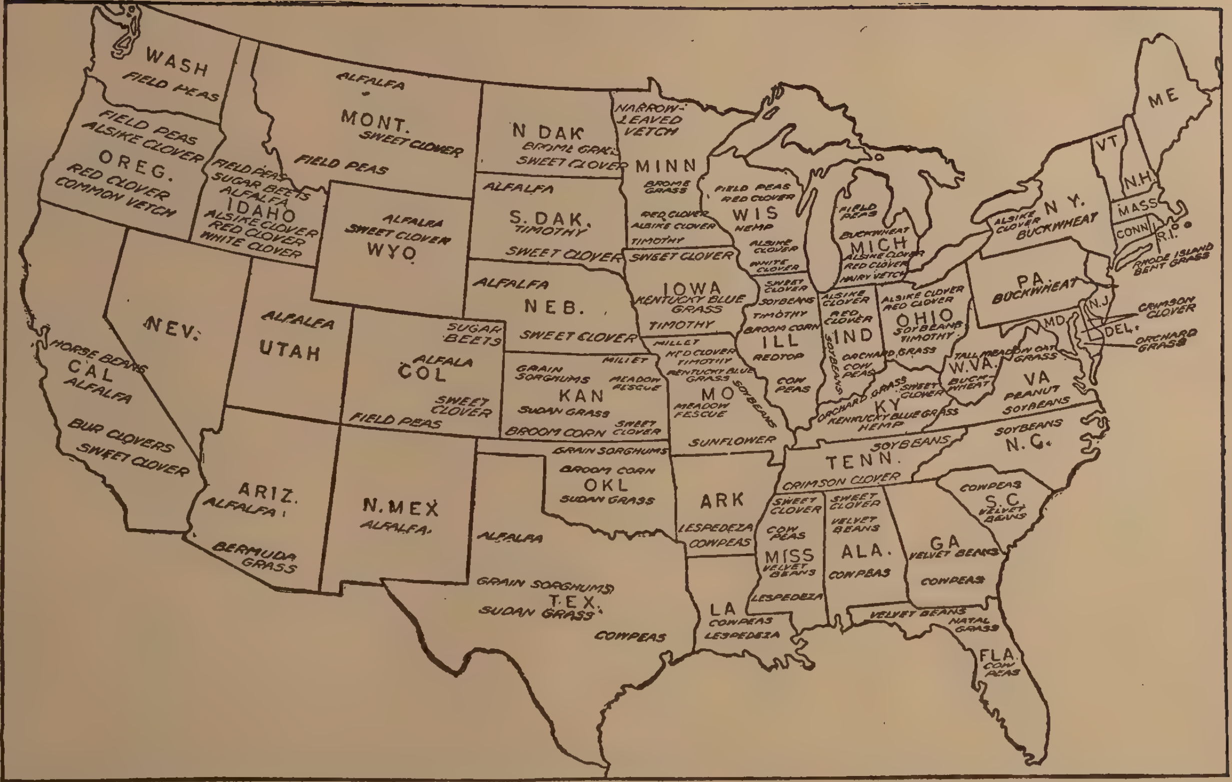
WASH
FIELD PEAS
OREG.
FIELD PEAS
ALSIKE CLOVER
RED CLOVER
COMMON VETCH
CAL
HORSE BEANS
ALFALFA
BUR CLOVERS
SWEET CLOVER
IDAHO
FIELD PEAS
SUGAR BEETS
ALFALFA
ALSIKE CLOVER
RED CLOVER
WHITE CLOVER
NEV.
MONT.
ALFALFA
SWEET CLOVER
FIELD PEAS
WYO.
ALFALFA
SWEET CLOVER
UTAH
ALFALFA
ARIZ.
ALFALFA
BERMUDA GRASS
COL
SUGAR BEETS
ALFALFA
SWEET CLOVER
FIELD PEAS
N.MEX
ALFALFA.
N DAK
BROME GRASS
SWEET CLOVER
S. DAK.
ALFALFA
TIMOTHY
SWEET CLOVER
NEB.
ALFALFA
SWEET CLOVER
KAN
GRAIN SORGHUMS
MILLET
MEADOW FESCUE
SUDAN GRASS
BROOM CORN
SWEET CLOVER
OKL
GRAIN SORGHUMS
BROOM CORN
SUDAN GRASS
TEX.
ALFALFA
GRAIN SORGHUMS
SUDAN GRASS
COWPEAS
MINN
NARROW-LEAVED VETCH
BROME GRASS
RED CLOVER
ALSIKE CLOVER
TIMOTHY
IOWA
SWEET CLOVER
KENTUCKY BLUE GRASS
TIMOTHY
MO
MILLET
RED CLOVER
TIMOTHY
KENTUCKY BLUE GRASS
SOYBEANS
MEADOW FESCUE
SUNFLOWER
ARK
LESPEDEZA
COWPEAS
LA
COWPEAS
LESPEDEZA
WIS
FIELD PEAS
RED CLOVER
HEMP
ALSIKE CLOVER
WHITE CLOVER
ILL
SWEET CLOVER
SOYBEANS
TIMOTHY
BROOM CORN
REDTOP
COW PEAS
MICH
FIELD PEAS
BUCKWHEAT
ALSIKE CLOVER
RED CLOVER
HAIRY VETCH
IND
ALSIKE CLOVER
RED CLOVER
SOYBEANS
ORCHARD GRASS
COW PEAS
OHIO
ALSIKE CLOVER
RED CLOVER
SOYBEANS
TIMOTHY
KY
ORCHARD GRASS
SWEET CLOVER
KENTUCKY BLUE GRASS
HEMP
TENN.
SOYBEANS
CRIMSON CLOVER
MISS
SWEET CLOVER
COW PEAS
VELVET BEANS
LESPEDEZA
ALA.
SWEET CLOVER
VELVET BEANS
COWPEAS
GA
VELVET BEANS
COWPEAS
FLA.
VELVET BEANS
NATAL GRASS
COW PEAS
S.C.
COWPEAS
VELVET BEANS
N.C.
SOYBEANS
VA
TALL MEADOW OAT GRASS
PEANUT
SOYBEANS
W.VA.
BUCKWHEAT
MD
DEL.
N.J.
CRIMSON CLOVER
ORCHARD GRASS
PA.
BUCKWHEAT
N.Y.
ALSIKE CLOVER
BUCKWHEAT
VT
N.H.
ME
MASS
CONN
R.I.
RHODE ISLAND BENT GRASS

FIG. 76.—Map of the United States indicating the more important sections where different field seed are produced commercially. (U. S. Dept. Agr. Yearbook 1917, p. 500.)

STUDY QUESTIONS ON CHAPTER XII

1. Essentially, of what does a seed consist?
2. What processes are going on continuously in a seed? Can life in a seed be demonstrated in any way except by germination?
3. What is dormancy? By what is it induced?
4. To what do we refer as "hard" seed? Under what conditions are they found and what is their value?
5. A man is offered two lots of sweet clover seed, one with 30 per cent hard and 5 per cent dead, the other 15 per cent dead but none hard. What can he afford to pay for each, when seed which germinates readily is worth 10 cents per pound?
6. When weedy material is fed, is it possible to be certain that live weed seed are not scattered with the manure?
7. What takes place in the germination of a seed? What conditions are necessary for germination?
8. In handling seed what precautions are necessary to prevent injury from drying? From premature germination? From heating?
9. Make a chart of the common crops, giving the maximum age at which, by increasing the rate of seeding one-half, seed can still be used.
10. To what extent and under what conditions can weed seed be destroyed by plowing them under?
11. In a year in which oats are light in weight per bushel you find that you can fan thoroughly and increase the size and weight of grain materially. Will you fan? Why?
12. Objection was made to the seed-staining act, the claim being made that as no one would buy red stained seed, it was a law in restraint of trade. How would you answer this statement?
13. You wish to purchase pure seed of a certain crop variety. How can you be sure to get what you want?
14. Explain the difference between *certified* seed and *verified* seed.
15. What conditions limit the areas of seed production of the standard crops grown in your section?

APPLICATION ASSIGNMENTS ON CHAPTER XIII

1. The following advertisement is called to your attention: "The ——— Seed Company has obtained a supply of a wheat developed from a few kernels found recently in a tomb unearthed in Egypt. The seed was clasped in the hand of a mummy and was in a wonderful state of preservation after 6,000 years. This wheat has proven extremely valuable and ———." Criticize the statement.
2. A sample of your winter wheat looks very good but when tested immediately after threshing germinates only 50 per cent. Will you use it for seed? Why?
3. A sample of sweet clover seed germinates only 60 per cent. The other 40 per cent looks all right but does not germinate. Explain this and give the remedy.

4. You are offered two lots of sweet clover seed equal in quality except that the first, which is priced at 9 cents per pound, shows a germination of only 60 per cent, with 34 per cent of hard seed, while the second, priced at 11 cents, germinates 95 per cent, with no hard seed. Which will you buy and why? If it were Grimm alfalfa seed priced at 40 and 46 cents, which would you buy and why?
5. A lot of timothy and alsike seed which you had purchased was sampled and sent to the seed laboratory for analysis. Before the report came back you planted the seed. The report showed 600 Canada Thistle seed per pound. Your field becomes infested. What can you do?
6. Last year a heavy crop of cockle burs matured and scattered its seed over one of your fields. How will you handle this field to eliminate future trouble from this weed?
7. The hay and grain you are feeding was shipped into the community and contains seed of noxious weeds. How will you handle the manure in order to minimize the danger of spreading weeds?
8. A local seed company with a supply of excellent seed of all kinds was forced into bankruptcy and nothing was sold for two years. The seed was then placed on the market at half price. What seed will you be safe in buying?
9. A trucker ordered Early Wakefield cabbage seed for an 18-acre field and, after having planted and transplanted and tended with much hand labor for six weeks, he discovered he had been supplied with rape seed instead of cabbage. What can he expect by going into court? Why?
10. You wish to grow certified seed of a certain variety of oats. How will you proceed in order to be certain that it will be certified?
11. With a 300-acre farm you are considering the advisability of making a specialty of seed production. Outline the factors you will consider and the list of crops and the varieties you believe would be profitable for you to grow.

CHAPTER XIII

THE CORN CROP

Indian corn (*Zea mays*) is of the utmost importance to the American people and this has been equally true from the very beginning of our history. Facts showing the position of this crop in the agriculture and commerce of the world have been presented in Chapter I, while its position in the agriculture of the United States is shown in Chapters II and III. Figs. 4, 21, 33.

351. History of Corn. Although there is some difference of opinion, it is rather generally believed that corn is of American origin. Harshberger[1] suggests that the corn plant probably was cultivated first in a high plateau region of Central or South America. This region is the native habitat of teosinte and gama grass which are closely related botanically to corn. He states that the cultivation of corn probably started in this region about the beginning of the Christian era, spreading rapidly both to the North and to the South, reaching the Rio Grande about 700 A.D. and as far as Maine by about 1000 A.D.

Montgomery[2] suggests that both corn and teosinte doubtless trace back to a plant resembling gama grass, the plant having a tassel at the top of the central stalk or culm and tassel-like structures on the long lateral branches, all the tassels bearing both male and female flowers. In the process of evolution and diversification those plants survived which most successfully and efficiently used food materials in producing seed. As the pollen tends to fall to lower levels, that from the lower tassels was often lost, while the female flowers from the uppermost tassels were least likely to be pollinated and produce seed for reproduction. In time the lateral branches gradually were shortened as the seed plants with long branches were lost, due to the branches breaking down. As these branches were shortened the seed parts were enclosed by the modified leaves,—the husks.

352. Corn-Growing by the American Indians. When this continent was first discovered by European explorers, the American Indians of the North Atlantic coast were extensive corn growers; and we are told that the early colonists would have perished by starvation except for the corn stores of the Indians. These colonists soon learned the art of growing corn as taught them by these friendly people.

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[1] Harshberger, John W.—*Maize,—A Botanical and Economic Study*. Bot. Lab., Univ. Pa. Vol. 1, No. 2. 1893.

[2] Montgomery, E. G.—"What Is an Ear of Corn?" *Pop. Sci. Mo*. Vol. 68, p. 35. 1906.

Carrier[3] believes, from a careful study of the early descriptions of corn, that both the quality and yield of corn grown by the Indians along the Atlantic coast at the time of the English settlements compared quite favorably with that of the average farmer in those sections today, but that it was probably inferior to the improved strains grown by the best farmers. He states that the Indians had developed types of corn suitable to the various soil and climatic conditions of America, such as the flint for the North, the prolific for the South, and the dents for the corn belt, which the white farmers have not been able greatly to improve.

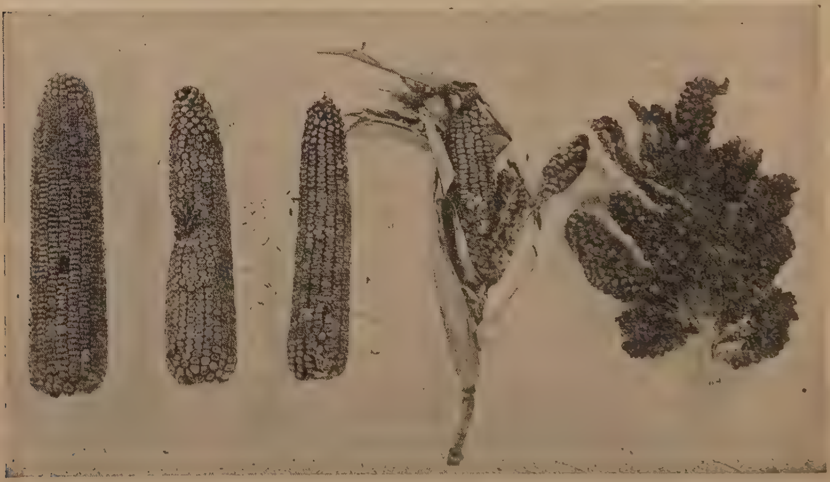

FIG. 77.—It is believed that the corn ear of the present day traces back to a branched tassel on which both the male and female flowers were borne.

A corn secured from the Mandan Indians at Mandan, N. D., by Oscar H. Will of Bismarck in 1882, having been grown by these Indians for at least 200 years previously, is now grown extensively throughout the Northwest and continues to the present to be the heaviest yielding corn for general use in that section. This corn is the Dakota White Flint.[4]

353. Indian Seed Selection and Storage Practices. The American Indians practiced rather rigid seed selection and had fairly definite standards.[5] The ears were selected each fall and the husks braided together so that a braid would contain about 50 ears, these braids being about 5 feet long. The braids were hung up to dry before being stored. In many tribes the selection and storage of seed corn was accompanied by appropriate ceremonies which tended to emphasize the importance and necessity of careful seed corn selection. Will and Hyde give particularly complete and interesting information on the corn culture of the agricultural tribes of the upper Missouri.

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[3] Carrier, Lyman—"A Reason for the Contradictory Results in Corn Experiments." *Jour. Amer. Soc. Agron.* Vol. 11, No. 3, p. 107. Mar., 1919.

[4] Olson, P. J., *et al*, "Corn for North Dakota." *N. Dak. Agr. Expt. Sta. Bul.* 207. 1927.

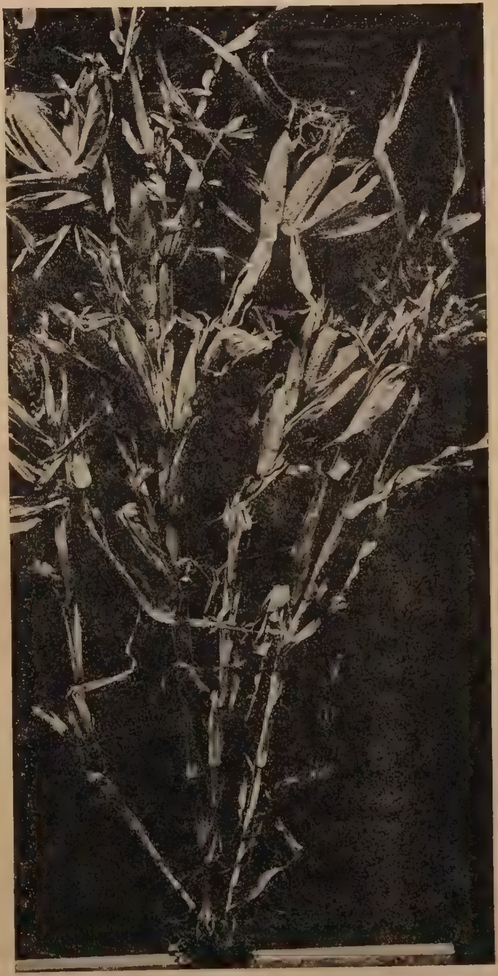

FIG. 78.—A corn plant which shows the tendency to produce a branch at each node of the main stalk and with the flower parts at the end of each branch. Observe both male and female flowers at the end of the lower branches. *Try to account for this growth, having in mind the average corn plant and its possible ancestry.*

The Indians of both the New England and middle western states used the cache for storing corn. These caches were holes dug in the ground, usually to a depth of 5 to 7 feet and several feet in diameter. They were either concave or cylindrical. Caches were always dug on the higher ground so as to avoid danger from seepage waters. In some tribes these were dug in the floor of dwellings, but, in others, outside. Fires were often started in the caches to dry them out before storing corn. The bottoms and sides were often lined with grasses and bark. The corn was put into these in braids or, if shelled, it was placed in deer skin sacks, or, in forest regions, in bags

[5] Will, George F., and Hyde, George E.—*Corn Among the Indians of the Upper Missouri*. Wm. Harvey Miner Co. St. Louis. 1917.

of cedar bark. After being filled the cache was covered over with earth and hidden.

354. Indian Methods of Planting. Biggar[6] gives some information on the Indian method of planting corn. He outlines 3 methods. In the Hopi method, ascribed to the southwest, a stick is pressed into the soil with the foot. Holes are made from 8 to 12 inches in depth. Into these holes 20 kernels are dropped. The hills are about 10 feet apart. The number of plants per hill may seem excessive but none are thinned out, this being done as protection against sun and wind. In the Omaha or mound method, the soil was pulverized and heaped into mounds about 18 to 24 inches in diameter, higher at the north and sloping toward the south. Seven kernels were planted in the mound. Sometimes a ditch was dug around the mound into which water was poured in dry seasons. In the hill method of planting corn the entire field was not dug up or pulverized but only space enough for each hill. Each spring the stalks were removed from the hills, which were pulverized and used again for planting. The hills were from 2 to 5 feet apart.

The Indians in different parts of the country are reported to have grown flint, flour, dent, and sweet corn varieties. The gourd seed corn was a large, rough, soft dent corn, and many of our dent varieties of today are believed to have been obtained from either intentional or accidental crosses between gourd seed and flint varieties.

THE CORN PLANT

Corn belongs to the *Gramineæ* or grass family. The characteristics of this group of plants have been described in Chapter IV. The description of the corn plant given here has to do with the different parts of the plant as they may relate to the handling of the corn crop.

355. Roots. The germinating corn kernel sends out a root sprout from the tip of the kernel, this growth starting even before the plumule has emerged from the hull. From this root sprout a temporary root system develops, which anchors the seed and absorbs water and perhaps some plant food during the seedling stage. Shortly after the plumule has emerged and the leaves have opened to the light, the permanent roots form at nodes usually about an inch below the surface. The nodes are very close together at this point, and the roots may come from several adjacent nodes. The permanent roots are fibrous and extend out laterally and downward into the soil. They may penetrate 5 or 6 feet downward and in the field the lateral root growth is such that the roots from adjoining hills will meet and intercross in the middles between the rows. These roots are much branched in the top soil and will grow in the very surface soil if it is not stirred or allowed to dry out. (117)

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[6] Biggar, H. Howard—"The Old and the New in Corn Culture." *U. S. Dept. Agr. Yearbook 1918*, pp. 123-136.

A third type of root is the brace root which may arise at several nodes just above the surface. These roots are stiff, horny projections which turn toward the soil. They do not branch unless they enter the soil, when they may branch profusely. The chief function of the brace roots is probably that indicated by the name.

356. Stalks. The culm or stalk of the corn plant may vary in length from less than 2 to more than 25 feet. Early pop and sweet corn varieties or varieties of flint and dent corns grown in sections with a short growing season and low rainfall are extremely short, while certain varieties grown on fertile soils in regions with long growing seasons may grow to extreme heights.

The stalk consists of nodes,—or joints, and internodes,—or the portion of the stalk between the nodes. One side of the lower internodes is grooved and in this groove at the base of each internode is found a bud. When these buds develop they may produce a tiller or sucker, or an ear. A corn plant, with proper inducement, may produce an ear or a branch from each node below the node at which the ear is ordinarily borne.

The length growth is due to elongation of the internode at a point just above the node. Enlargement in diameter takes place from within and is rather limited.

On the outside of the stalk there is a thin layer (the epidermis) of transparent tissue which renders the stalk impervious to moisture and tends somewhat to protect the stalk from insects and diseases. Just under the epidermis is a mass of fibrovascular bundles bound together forming a hard woody wall which gives the stalk its strength. Inside this wall the stem is filled with pith, through which run widely separated fibrovascular bundles.

357. Leaves. The leaves of the corn plant are alternately arranged, one above another (two ranked). The leaf consists of an elongated leaf blade, regular in width but with a wavy margin, and a leaf sheath, which arises at one of the nodes and clasps the stem above the node. Leaves of different strains may vary considerably in length, width and number, and this variation seems to influence the adaptation of the strain.

358. Flowers. The male or staminate flowers are borne in two-flowered spikelets in the tassel. Each flower has 3 anthers enclosed in flowering glumes (lemma and palea). The anthers usually start shedding pollen before the silks emerge and continue after the silks are all out. Each anther produces about 2,500 pollen grains, and it is estimated that approximately 20,000 pollen grains are available for each kernel while only one can actually fertilize the ovary. The abundance of pollen makes possible the perfect fertilization of the ear.

The female or pistillate flowers are borne on a core or cob. The cob and grains constitute the ear. Like the tassel, the cob is borne on the end of a branch and the cob may be considered as a modified tassel framework. The husks surrounding the ear are modified leaves, primarily modified leaf sheaths. The modified branch with greatly shortened internodes is called the shank. The female flowers are borne two in a spikelet and the glumes are the chaff which adheres to the cob. Only one flower in each spikelet develops, except in the case of Country Gentleman sweet corn where both develop. Each flower that is not sterile sends out a silk which is the stigma and style of the flower. The exposed portion of this silk is somewhat hairy and covered with a mucilaginous substance which serves to hold the pollen grain and favors its germination.

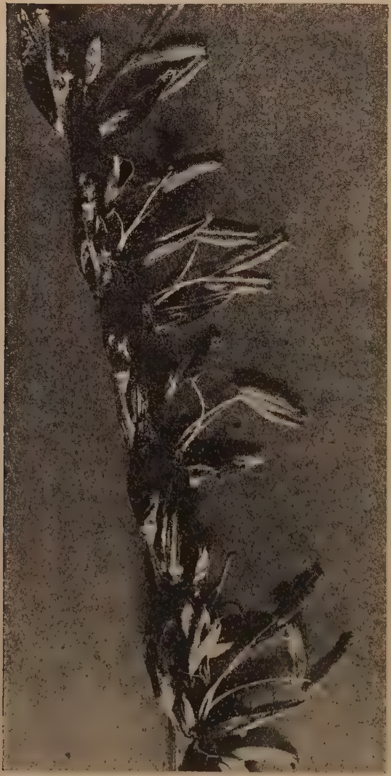

Fig. 79.—A portion of the corn tassel showing the pollen sacks of the male flower.

359. Fertilization. In fertilization the pollen grain falls on the stigma of the silk and germinates, sending a tube through the silk to the ovary. Following closely behind the growing tip of this pollen tube two sperm nuclei pass through the silk to the ovary. The pollen tube behind these two nuclei may disappear even before they have reached the ovary. The two sperm nuclei on reaching the ovary separate and one unites with the egg nucleus to form the embryo nucleus, while the other unites with two polar nuclei to form the endosperm nucleus. The endosperm and the embryo of the germ are affected immediately by the male nuclei, while the ovary wall,—the pericarp or husk of the developed grain,—is mother tissue and is not modified by fertilization.

Corn is normally cross-pollinated, self-pollination being hindered by the isolation of the male and female flowers on different parts of the plant.

Waller[7] found 5.13 per cent self-pollination in corn. He states that this figure may not represent the per cent of self-pollination taking place under all field conditions. Humidity and wind are factors which help in determining the zone of pollen distributio for individual plants.

Kiesselbach[8] planted isolated hills of white corn in a field of yellow, with the flowering periods of the 2 strains of corn identical, and concluded that self-fertilization as it occurs ordinarily in the field in Nebraska does not exceed 1 per cent. Estimates have generally placed the amount of self-fertilization at less than 5 per cent.

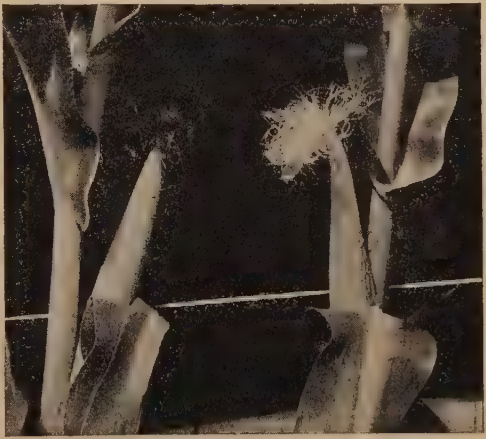

FIG. 80.—The corn silks which protrude from the husk are the elongated pistils of the female flowers.

360. Pollen and Silk Formation. Kiesselbach made detailed studies during flowering time of 120 plants of each of 14 varieties of corn for 2 years and of 9 varieties for a third year. He found that as an average, after the tassel was first visible it was 6.3 days until the tassel was entirely out; 6.4 days until shedding of pollen began; 8.3 days until the silks first showed; 9.8 days until pollen was shed at the maximum rate; 10.7 days until the silks attained their maximum length; 12.0 days until the silks showed fertilization; and 12.7 days until the tassel ceased to shed pollen.

After the pollen began to shed it was 2.0 days until silks first appeared; 3.4 days until pollen was shed at a maximum rate; 5.6 days until silks showed fertilization, and 6.4 days until the pollen ceased to shed.

Silks appeared to be receptive to pollen before they had emerged from the shoot and for a period of 2 weeks afterwards. When the silks were cut off before they had been fertilized, pollen applied to the cut ends did not result in fertilization, but after the silks had grown out they became receptive again. It is this principle which enables a plant breeder to use Jenkins' method of making self-pollinations.

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[7] Waller, Adolph E.—"A Method for Determining the Percentage of Self-Pollination in Maize." *Jour. Amer. Soc. Agron.* Vol. 9, No. 1, p. 37. Jan., 1917.

[8] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20.* 1922.

Kiesselbach states that pollen grains have retained fertilizing power 70 to 80 hours after leaving the anthers, under laboratory conditions; but under a temperature range of 70° to 100° F. and an atmosphere ranging from 30 to 70 per cent relative humidity, pollen had practically lost its viability in 24 hours.

Alberts[9] states from observations made in 1925 that early varieties required a shorter period of time to reach the silk stage than late varieties but that the period from the time of silking to the time of denting was approximately 40 days for both early and late varieties and for both early and late plantings. Late varieties retained green leaves longer after denting than early varieties.

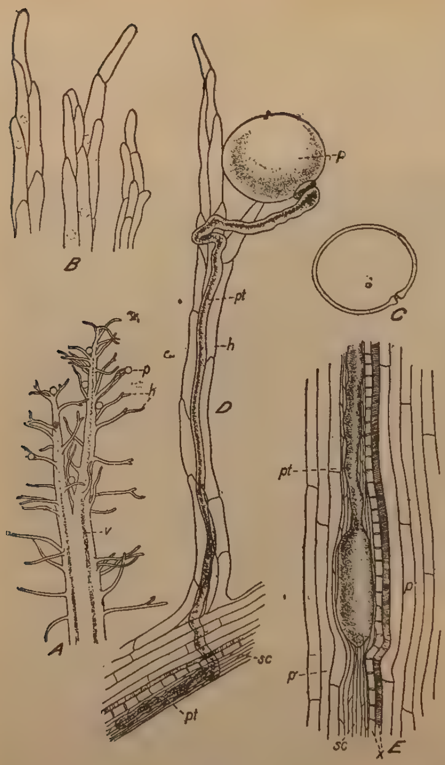

FIG. 81.—Pollination in the corn flower. *A*, end of a silk; *p*, pollen grain; *v*, fibrovascular bundle; *h*, hairs. x 35. *B*, tips of the hairs of the silk. It is on these hairs that most of the pollen grains lodge. x 250. *C*, section of a pollen grain showing germ pore. x 250. *D*, single hair of the silk showing the general manner in which the pollen tubes penetrate the sheaf cells of the fibrovascular bundle of the silk; *p*, pollen grain; *h*, hair; *pt*, pollen tubes; *sc*, sheaf cells of the fibrovascular bundles. x 250. *E*, longitudinal section of a fibrovascular bundle of a silk showing the position of the pollen tube as it grows down the silk; *sc*, sheaf cells; *x*, xylem element; *t*, parenchyma cells of the silk; *pt*. pollen tube, showing the enlarged tip. x 250 (E. C. Miller, Volume 18, No. 5, Journal of Agricultural Research).

TYPES AND VARIETIES OF CORN

361. Recognized Types of Corn. Sturtevant[10] in 1899 described 6 specie-groups of corn: (1) *Zea tunicata* (or pod corn) has each kernel enclosed in a pod or husk, while the ear itself is also enclosed in a husk. (2) *Zea everta* (pop corn) is characterized by an excessive proportion of horny endosperm and the small size of the kernel and ear. The best varieties have a horny endosperm throughout. (3) *Zea indurata* (flint corn) is characterized by having the starchy endosperm enclosed in a corneous or horny endosperm. The corneous endosperm varies with the different varieties. (4) *Zea indentata* (dent corn) is characterized by the presence of corneous endosperm at the sides of the kernel, only the starchy endosperm extending to the crown of the kernel. With the drying and shrinking of the starchy matter the crown is drawn in and becomes indented in various forms. (5) *Zea amylacea* (soft corn) is characterized by the entire absence of corneous endosperm. Due to the uniform shrinking of the entire kernels in ripening there is usually little or no indentation. (6) *Zea saccharata* (sweet corn) is characterized by the translucent appearance of the kernels and their more or less crinkled, wrinkled, or shriveled appearance.

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[9] Alberts, H. W.—"Relation of Time of Planting Corn to the Time of Silking, Denting, and Senescence." *Jour. Amer. Soc. Agron.* Vol. 18, No. 5, p. 380. May, 1926.

[10] Sturtevant, E. L.—"Varieties of Corn." *U. S. Dept. Agr. Off. Expt. Stas. Bul. 57*, pp. 12-18. 1899.

Other distinct types of corn have been described but none of them are important commercially.

362. Varieties of Corn. Sturtevant listed 507 named varieties of corn in 1899. Of these, 323 were classed as dent; 69 as flint; 63 as sweet; 27 as soft; and 25 as pop corns. It has been estimated that there are now probably well over 1000 named varieties.

363. Variety Names Not Always Significant. Hughes[11] pointed out in 1913 that different strains of the same variety as grown on different farms may differ as much in ability to yield as seed of distinctly different varieties. He obtained seed of Silver King from 12 prominent growers and found differences of as much as 20 bushels per acre in yield as well as marked differences in maturity and general habit of growth.

364. Corn Yield Tests. In addition to the comparison of corn varieties made by the experiment stations considerable interest has developed in recent years in corn yield tests, recognition being given to the fact that different strains of the same variety may differ greatly in yield. In Iowa, a state test was inaugurated in 1920, with the state divided into 12 districts and with a testing field in each district in order to allow for differences in adaptation of the different corn strains entered. Approximately 500 entries have been included in the test per year, contestants paying an entry fee of $3.00 to cover a part of the expense of the work. Each entry is given a number so that the corn is grown through the year and the yield results are determined without knowing the name of the entrant. All samples entered are grown side by side with all conditions as uniform as they can be made. Yields are compared on the basis of uniform soil and growing conditions for each entry and the same moisture content in the shelled corn.

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[11] Hughes, H. D.—"Silver King.—A Corn for Northern Iowa." *Iowa Agr. Expt. Sta. Bul. 138.* 1913.

365. Varieties Recommended. The different strains of a variety have some characteristics in common. In 1928, a survey was made of the varieties of corn recommended by the different state experiment stations. Table *365a,* p. 309.

366. Relative Value of White and Yellow Corn. In *Wallace's Farmer* for April 22, 1904, a correspondent from Nebraska stated that he was acquainted with a large number of farmers and feeders in Nebraska and had never found one who did not agree that the feeding of yellow corn puts on more flesh per bushel than white. The belief of investigators at the time was that there was no consistent difference in the composition of white and yellow corn.

Rice *et al.*[12] report experiments comparing the feeding value of white and yellow corn for breeding sows and fattening pigs at the Illinois station from 1920 to 1925. They found that white corn was not as satisfactory as yellow corn for growing and fattening pigs under restricted dry-lot conditions. The lower value of the white corn was apparently due to a deficiency in vitamin A. Young pigs were much more quickly affected by the white corn ration than old pigs, evidence of malnutrition developing much earlier in the young pigs. They state that if pigs are raised on normal rations containing an adequate supply of vitamin A they may store enough of this vitamin in their bodies to carry them through a gain of 100 to 125 pounds on white corn rations just as economically as on yellow corn. Eventually, however, malnutrition, due to lack of vitamin A, will develop.

A considerable number of stations report the results[13] of feeding tests comparing the value of white and yellow corn in various rations.[14] In general they find yellow and white corn to be about equal in value when the stock are on pasture or are given some supplement rich in the fat soluble vitamin but that the white corn is not satisfactory in dry-lot feeding without these supplements, while yellow corn gives good results. Green alfalfa hay fed with white corn seems to furnish the vitamin necessary for satisfactory growth. White corn is as good as yellow corn for horses, dairy cattle, beef cattle, and sheep if fed ordinary balanced rations and given green-colored hay. Yellow corn is superior to white corn for poultry which do not receive plenty of fresh green feed, clover or alfalfa.

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[12] Rice, J. B., *et al.*—"A Comparison of White and Yellow Corn for Growing and Fattening Swine and for Brood Sows." *Ill. Agr. Expt. Sta. Bul. 281.* 1926.

[13] "Yellow *vs.* White Corn for Stock Feeding." *Wis. Agr. Expt. Sta. Bul. 339,* p. 125. 1921.

[14] See reference 12.

365a. Corn varieties as recommended by agronomists in various sections of the United States.

	GENERAL TYPE GROWN	VARIETIES RECOMMENDED
New England	Early flints, some early dents	Early Lakeside, Sanford, Longfellow, Golden Nugget
N. Y., Mich., Wis., Minn., S. Dak.	Early dents	Golden Glow, Minn. 13, Picketts, Silver King, Rustler
Iowa, Ill., Ind., Ohio	Medium dents	Reid Y. D., Boone Co. White, Silvermine, Champion White Pearl, Clarage, Leaming, Silver King
Pa., Md., N. J., Del.	Medium dents	Reid Y. D., Johnson Co. White, Clarage, Leaming, Lancaster Sure Crop
Nebraska	Medium early dents	Hogue Yellow Dent, Neb. White Prize, Reid Y. D., N. W. Dent
Kansas	Medium dents	Pride of Saline, Commercial White, Kansas Sunflower
Mo., Ky., W. Va.	Late dents	Reid Y. D., Boone Co. White, Commercial White, St. Chas. White
Va., N. C., S. C., Ga., Fla., Tenn.	Late dents and prolific types	Reid Y. D., Boone Co. White, Eureka, Cockes Prol., Whatley's Prol., Hickory King
Arkansas, La., Miss., Ala.	Prolific and some late dents	Hasting's Prolific, Mosby's Prol., Calhoun Red Cob, Mex. June, Paymaster, Delta Prol.
Okla., Tex., N. Mex., Ariz.	Dents and prolific	Reid Y. D., Sure Cropper, Chisholm, Mex. June, Hasting's Prol.
Mont., Idaho, N. Dak.	Early flints, very early dents	Dak., White Flint, N. W. Dent, Minn. 13 and 23, Gehn F. Silver King
Wash., Oregon	Early dents	Thayer's Y. D., other early dents and flints
California	Dents and flints	Leaming, Reid Y. D., Cal. Dent
Wyo., Col., Idaho, Utah	Early dents, flints	Leaming, Minn. 13, Silver King, Australian W. Flint

367. Adaptation of Corn,—Strains and Varieties. Most of our varieties of corn contain numerous strains and any one of our ordinary standard corn varieties grown under widely different environmental conditions would tend to change in physical appearance and in genetic composition. Reid Yellow Dent corn grown in southern Minnesota for a period of years would come to differ materially from the same variety grown and selected in Missouri.

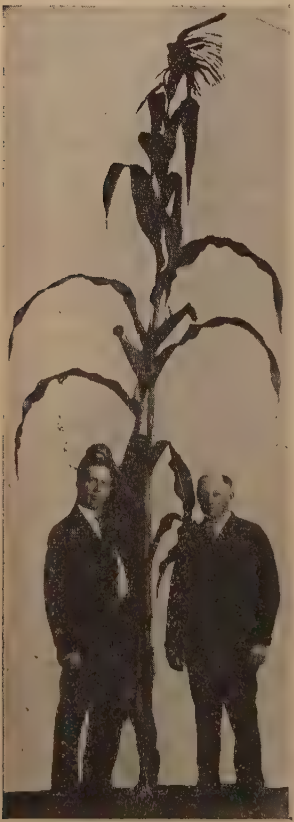

FIG. 82.—In Iowa "where the tall corn grows."

We have wide differences in the same variety of corn and extreme variations in physical type between different varieties. In height, a mature corn plant may make a growth of only 18 inches or 2 feet in the case of some of our early flints, to between 20 and 25 feet in the case of some of our dent varieties adapted to the tropics. The ears may vary from around 2 inches in length and less than 1 inch in diameter for the Tom Thumb pop corn to 12 to 15 inches in length and 3½ inches in diameter in a number of dent varieties. Some varieties produce stalks bearing only 1 ear, while others produce 5 or 6 ears and in certain cases as high as 12 ears per plant. These and numerous other variations make it possible to secure a strain or variety adapted to almost any environment.

The immediate effect of moving seed corn from one locality to another is illustrated in work reported from the Arkansas and Kansas stations. Seed corn of each of 7 varieties was collected from 3 sections, (a) north of N. latitude 38°, (b) between 35° and 38°, and (c) south of 35°, and compared at the Arkansas station,[15] which is located between 35° and 38° N. latitude. Yields were as shown in Table *367a*.

At the Kansas Station,[16] home grown seed of 7 different varieties was compared over a 7-year period with seed of the same varieties introduced from 7 other states. The Kansas grown seed yielded 6.47

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[15] Newman, C. L.—"The Comparative Yield of Corn from Seed of the Same Variety Grown in Different Latitudes." *Ark. Agr. Expt. Sta. Bul. 59.* 1899.

[16] Ten Eyck, A. M.—"Variety Tests of Corn." *Kans. Agr. Expt. Sta. Bul. 193.* 1913.

367a. Yield obtained with seed from the North, from the region in which the test was made, and from the South. Arkansas.

Name of Variety	Number of Tests	Seed Grown North of 38 N. Latitude	Seed Grown between 35 and 38 N. Latitude	Seed Grown South of 35 N. Latitude
Leaming	21	21.0	26.2	17.2
Golden Beauty	20	32.8	45.8	50.5
Hickory King	23	24.9	31.8	29.1
Golden Dent	26	21.5	25.1	25.3
Champion White Pearl	11	22.6	32.0	30.1
Early Mastodon	16	33.5	33.8	33.5
Average	155	25.8	32.8	31.5

bushels more grain as an average of 40 crops and 145 pounds less stover than seed from other sources. Boone County White corn from Indiana with a gain of 2.33 bushels was the only imported seed which yielded more than seed of the same variety grown in Kansas.

Hughes and Robinson[17] report that in Iowa seed moved from the eastern to the western part of the state and vice versa produced fully as good yields as locally grown seed.

Three varieties of corn ranging from 105 to 125 days in maturity were compared in eastern, central, and western Kansas.[18] In the east the rainfall was about 35 inches, in central Kansas 25 inches, and in the west below 20 inches.

367b. Yields of three varieties of corn under varying amounts of rainfall. Kansas.

Variety	No. of Days to Mature	Eastern	Central	Western
Kansas Sunflower	125	44.3	20.1	10.1
Pride of Saline	115	42.1	21.8	13.3
Freed White Dent	105	38.8	27.2	18.5

368. Adaptation with Reference to Insect Pests. The variety of corn best suited to a locality may be dependent upon other factors than maturity or ability to yield. The relation of shuck cover to insect infestation in the field in southern states has been reported by Kyle.[19] The per cent of the ears infested with weevils was as follows: a poor shuck covering, 52; good shuck cover with worm holes, 38; a good shuck cover without worm holes, 9. The 3 groups of ear types infested with beetles was 96, 93, and 56 per cent, respectively. When the shucks extended 4 to 6 inches beyond the tip of the ear, the per cent of weevil infestation in the field was 9; 2 to 3 inches, 22; no extension, 100 per cent weevil infested. After being in storage for 10 months, ears having poor shuck cover had 97 per cent infestation with weevil and 100 per cent with beetles; good shuck cover with worm holes, 55 per cent weevil infestation and 100 per cent beetle infestation; good shuck cover without worm holes, 4 per cent weevil infestation and 75 per cent beetle infestation.

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[17] Hughes, H. D., and Robinson, J. L.—"High Yielding Varieties and Strains of Corn for Iowa." *Iowa Agr. Expt. Sta. Bul. 265.* 1929.

[18] Cunningham, C. C., and Wilson, B. S.—"Varieties of Corn in Kansas." *Kans. Agr. Expt. Sta. Bul. 227.* 1921.

[19] Kyle, C. H.—"Shuck Protection for Ear Corn." *U. S. Dept. Agr. Dept. Bul. 708.* 1918.

Dungan and Burlison[20] report that Mohawk, Blackhawk, and Champion White Pearl graded as 100 per cent in yield and Reid Yellow Dent 75 per cent, as an average for an 8-year period on the Alhambra field in southern Illinois where there are frequent and serious infestations with the chinch bug; while at Urbana, where the infestation is not serious, Reid Yellow Dent ranked as 100 per cent in yield and Champion White Pearl as 90 per cent.

COMPOSITION OF THE CORN PLANT

369. Stage of Maturity and Composition—Indiana. Jones and Huston (Indiana)[21] have studied the composition of corn at various stages of maturity, starting with the plant at about 4 feet high and carrying it through until complete maturity in the field. The results of these studies are reported in Table *369a*.

370. Maturity and Composition. North Dakota. Hopper[22] has made extensive studies of the analysis of corn at different stages of maturity. The average composition for all varieties tested at tassel, milk, dough, glazed, and ripe stages was as shown in Table *370a*.

370a. Analysis of corn varieties at different stages of maturity. North Dakota.

STAGE OF MATURITY	COMPOSITION OF DRY MATTER; PER CENT					
	Dry Matter	Ash	Crude Protein	Ether Extract	Crude Fiber	Nitrogen Free Extract
Tassel	13.48	8.53	11.65	1.68	27.66	50.48
Milk	18.47	6.49	8.95	1.57	26.08	56.91
Dough	25.02	5.51	8.22	2.20	22.52	61.55
Glazed	32.72	5.38	8.33	2.67	21.42	62.20
Ripe	43.01	5.00	8.19	2.97	20.29	63.58

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[20] Dungan, George H., and Burlison, W. L.—"Productiveness of Certain Varieties of Corn in Illinois. *Ill. Agr. Expt. Sta. Bul. 294.* 1927.

[21] Jones, W. J., and Huston, H. A.—"Composition of Maize at Various Stage of Its Growth." *Ind. Agr. Expt. Sta. Bul. 175.* 1914.

[22] Hopper, T. H.—"Composition and Maturity of Corn." *N. Dak. Agr. Expt. Sta. Bul. 192.* 1925.

369a. Pounds per acre of various plant food elements and digestible nutrients found in the corn plant at various stages of maturity. Indiana.

DATE	DRY MATTER	POTASH	PHOS. ACID	NITROGEN	CRUDE PROTEIN	CRUDE FAT	CRUDE FIBER	ASH	NITROGEN FREE EXTRACT	STARCH
July 24[a]	365	19.6	2.15	12	75	20	85	45	141	7
Aug. 28[b]	2284	41.7	10.5	35	218	25	601	136	1303	167
Sept. 10[c]	3087	46	12	44	272	47	630	164	1923	....
Sept. 24[d]	4052	49	17	45	283	101	761	194	2713	1030
Oct. 1[e]	4465	53	18	52	330	107	801	184	3042	1593
Oct. 8[f]	4706	46	21	55	346	133	869	191	3168	1608
Nov. 12A[g][1]	4627	44	20	53	315	135	911	177	3040	1646
Nov. 12B[h]	3630	30	17	43	270	111	639	110	2500	1254

[a] July 24—plants were about 4 feet high.
[b] Aug. 28—pollination was complete.
[c] Sept. 10—roasting ear stage.
[d] Sept. 24—kernels glazing.
[e] Oct. 1—kernels hardening, ready for silo.
[f] Oct. 8—ready to cut and put in shock
[g] Nov. 12A—cut and shocked; ready to husk.
[h] Nov. 12B—plants left to mature in the field.

[1] Light frosts occurred on October 10, 12, and 18. A killing frost occurred October 28.

He also determined the per cent of these materials in the ear, the stover, and the fodder at these stages of maturity for dent varieties. The results of this work are given in Table *370b*.

370b. Per cent composition and therms net energy per acre at different stages of maturity of dent corn. Hopper, N. Dak.

	DRY MATTER	ASH	CRUDE PROTEIN	ETHER EXTRACT	CRUDE FIBER	NITROGEN FREE EXTRACT	THERMS NET ENERGY PER ACRE
				Ear			
Tassel	....	...	....	...	....	....	....
Milk	19.60	2.95	12.46	2.04	19.36	63.19	705
Dough	38.40	1.86	10.84	3.18	11.87	72.25	1771
Glazed	50.72	1.55	10.64	3.74	9.61	74.46	2550
Ripe	58.22	1.54	10.49	3.83	8.98	75.16	2577
				Stover			
Tassel	....	...	....	...	....	....	966
Milk	19.11	7.37	7.48	1.36	28.86	54.93	1218
Dough	21.65	7.95	5.98	1.45	30.60	54.02	1201
Glazed	25.64	9.00	5.48	1.32	34.74	49.46	1151
Ripe	33.95	8.56	5.07	1.31	34.51	50.55	988
				Fodder			
Tassel	15.02	7.73	10.54	1.62	27.60	52.51	966
Milk	19.20	6.52	8.44	1.49	26.98	56.57	1923
Dough	26.12	5.56	7.88	2.12	23.25	61.19	2972
Glazed	33.77	5.37	8.00	2.49	22.50	61.64	3701
Ripe	43.42	4.88	7.91	2.62	21.14	63.45	3565

Hopper states that under North Dakota conditions the corn plant may be considered mature at the glazed stage, in so far as production of feed is concerned. No extreme differences in the average composition of dry matter of early, medium, and late varieties occurred, but some variations occurred which were consistent to the several stages of growth. Stover of the flint corn contained the higher per cent of dry matter and the higher per cent of crude protein in the dry matter at all stages. He states also that the tassel at the silking period seems to be the most significant time from which to reckon the date of development and maturity of the corn plant. The first period, from planting until tasseling, is variable according to the environmental conditions and the earliness and lateness of variety. The second, from tasseling to glazed, is quite constant and quite independent of environmental conditions, and earliness, and lateness of the variety. This second period averaged 41 days. He states that by observing the date of tasseling; that is, when 80 per cent of the plants have tasseled, it is possible to estimate the time when the corn will reach the milk, dough, and glazed stages. At an early frost date (100 days after planting) the early varieties, though short in stature, showed the largest feeding value as measured in therms of net energy.

371. Maturity and Production per Acre. Data are available from several states showing the proportion of total production at different stages of development.

371a. Pounds of dry matter per acre in corn at different stages of maturity. Summary.

Maturity	N. Y. Ann. Rpt. 1889	U. S. D. A. F. B. 97[a]	Kansas Bul. 30	Average
Ears in silk	3080	3670	....	....
Ears in milk	4660	5320	4480	5496
Ears glazing	7260	7110	4860	7342
Ears mature	7920	8020	5460	8523

[a] Comparison made in Michigan.

372. Proportion of Ear to Plant, Etc. Smith[23] determined the distribution of dry matter in leaves, stems, and ears of the corn plant at different stages of maturity as shown in Table *372a*.

372a. Per cent of leaves, stalks, and ears at different stages of maturity. Michigan.

Date Cut	Maturity	Weight of 100 Plants; Lbs.				Per Cent of Total Dry Matter in		
		Total Weight	Leaves	Stalks	Ears	Leaves	Stalks	Ears
Aug. 24	Milk	201.8	85.0	67.8	49.0	36.4	34.3	29.3
Aug. 31	Roasting ear.	195.0	76.0	66.5	52.5	33.6	25.5	40.9
Sept. 7	Glazed	210.3	82.0	69.5	59.8	30.0	25.5	44.4
Sept. 14	Ripe	176.5	49.5	64.0	63.0	21.8	31.9	46.3

Redding[24] presents figures showing that under Georgia conditions the grain represents 38.77 per cent of the whole plant's above ground portion when mature and the cobs 9.69 per cent, making the ear 48.46 per cent of the entire weight of the plant. Husks and shanks made up 11.13 per cent; leaves, 9.83; and the stalk, 29.28 per cent.

373. Elemental Composition of Corn Plant. Latshaw and Miller[25] give a complete elemental composition of the corn plant

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[23] Smith, Clinton D.—"Some Experiments in Corn Raising." *Mich. Agr. Expt. Sta. Bul. 154.* 1898.

[24] Redding, H. J.—"Corn Culture." *Ga. Agr. Expt. Sta. Bul. 30.* 1895.

[25] Latshaw, W. L., and Miller, E. C.—"Elemental Composition of the Corn Plant." *Jour. Agr. Res.* Vol. 27. No. 11. p. 857. 1924.

373a. Elemental composition of the corn plant. Pounds in one acre.

ELEMENT	WEIGHT IN POUNDS OF ELEMENT IN—							
	Entire Plant	Roots	Aërial Parts	Stubs 1 Ft. High	Roots and Stubs	Grain	Cobs	Cobs and Grain
Carbon	4967.55	349.04	4618.51	171.59	520.63	1592.06	487.90	2079.96
Oxygen	5066.17	359.55	4706.62	169.27	528.82	1612.65	489.40	2102.05
Hydrogen	711.60	47.19	664.41	22.64	69.83	247.83	67.79	315.62
Nitrogen	166.27	10.50	155.77	3.22	13.72	76.52	14.73	91.25
Phosphorus	23.15	.98	22.17	.04	1.02	12.09	1.01	13.10
Potassium	104.74	3.95	100.79	4.74	8.69	14.86	4.89	19.75
Calcium	25.82	5.03	20.79	.65	5.68	.89	.23	1.12
Magnesium	20.80	1.40	19.40	.61	2.01	7.12	1.17	8.29
Sulfur	19.31	2.06	17.25	.61	2.67	4.98	.22	5.20
Iron	9.74	4.30	5.44	.19	4.49	1.52	.26	1.78
Silicon	133.07	36.70	96.37	1.61	38.31	.42	1.42	1.84
Aluminum	12.19	8.09	4.00	.05	8.14	.81	.56	1.37
Chlorin	16.59	.90	15.69	.84	1.74	1.17	1.28	2.45
Manganese	3.67	.55	3.12	.07	.62	1.30	.32	1.62

expressed in pounds of the different elements removed from the air and soil in the production of an acre of corn.

374. The Heating Value of Corn. In the past when a large crop of corn has forced unusually low prices there has been considerable talk of using corn for fuel. DeBaufre[26] determined the heating value of corn and found that when the price per ton of Pittsburgh coal was 10, 12, 14, 16, 18, and 20 dollars the value of corn on the cob, for fuel, per bushel of 70 pounds, would be 20, 24, 28, 32, 36, and 40 cents, respectively, while the heating value of shelled corn, per bushel of 56 pounds, would be 16, 19, 22, 26, 29, and 32 cents, respectively.

USES OF CORN

375. Corn and Animal Production. The corn crop and the swine and cattle population are intimately interrelated. With the exception of limited areas from which corn is largely sold as grain, swine are found most abundantly where corn production is greatest. In these areas, too, the finishing of cattle for market is a prominent industry. On January 1, 1922, the 6 states, Iowa, Illinois, Nebraska, Missouri, Indiana, and Ohio, producing 48 per cent of the total corn crop in the United States in 1921, had within their borders about 45 per cent of the swine of the country and over 25 per cent of the cattle other than milk cows. In addition, these states in 1919 produced 32 per cent of the poultry and 35 per cent of the eggs of the United States.[27]

In recent years nearly 4,000,000 acres of corn each year have been made into silage and more than 2,500,000 acres cut for fodder, while large use is made of the stalk fields in pasturing animals. More than 2,000,000 acres of corn are being hogged off annually.

376. Corn as a Food. Corn, consumed either directly or in the form of meat and other animal products, is one of the principal sources of food of the American people.

In addition to meal, hominy, and similar natural products, we have many manufactured food products made from corn. The unripe ears, especially of certain sweet varieties, are a favorite vegetable on the American table and pop corn is specifically an American food product. The extent to which corn enters into the diet differs greatly in different parts of the country and among different nationalities. In the South, corn is used extensively on the best tables, while in the North, and particularly in the larger cities, little corn is so used.

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[26] DeBaufre, Wm. L.—"The Heating Value of Corn." *Jour. Amer. Soc. Agron.* Vol. 15, No. 1, p. 5. 1923.

[27] Leighty, C. E., *et al.*—"The Corn Crop." *U. S. Dept. Agr. Yearbook 1921*, pp. 164-165.

377. Sweet Corn. Sweet corn is grown generally in the United States for human consumption as roasting ears and in many sections the canning of sweet corn is an important industry. The principal states growing corn for canning are Illinois, Iowa, Maryland, New York, Ohio, Indiana, Minnesota, and Wisconsin. Three hundred and seven thousand acres were grown for this purpose in 1926.

Quality in sweet corn. Magoon,[28] considering the quality of canned corn, states that the most important thing in determining quality in corn is tenderness or toughness of the kernel hull. Toughness varies somewhat with the variety, but is particularly affected by the degree of maturity of the corn. From the standpoint of toughness the period in which first quality corn can be packed is very short. Next in importance is the relative proportions of the different constituents of the kernel, principally starch and dextrine. Dextrine or dextrine-like substances are responsible for the creamy texture found in first quality corn. The sugar content of the corn is placed third in importance as sugar may be added in canning.

Varieties of sweet corn. There are a large number of varieties of sweet corn; only a few are widely and favorably known. A few of these are as follows:

Golden Bantam. This sweet corn is undoubtedly the most popular variety of sweet corn for home gardens in the Central and Eastern states. The ears are 6 to 7 inches in length, about 1½ inches in diameter, and normally bear 8 rows of kernels, which are extra high in quality. The kernels when boiled are bright yellow in color.

Country Gentleman. This variety is extensively grown, producing a rather large stalk with a medium sized ear. The kernels are white, narrow and deep and crowded on the cob so that the rows are hardly apparent. This is a favorite variety with canners. It is comparatively late in maturity.

Stowell's Evergreen. This is a medium late variety extensively grown for canning purposes and by market gardeners. The ears average 8 to 9 inches in length and bear 16 to 20 rows of medium kernels.

Sunshine. Sunshine is a yellow variety introduced by the North Dakota Experiment Station. The car averages 7 to 8 inches in length, having 12 to 14 rows of broad, yellow kernels. The quality is excellent. It is a cross between Golden Bantam and Gill's Early Market.

378. Pop Corn. Pop corn is characterized by the large proportion of horny endosperm and the tendency to expand greatly and turn inside out or evert on being heated. Pop corn is grown for home use in all parts of the United States. For market, the crop is grown to a limited extent in several sections but the chief areas of commercial production are in Ida and Sac counties, Iowa, and Valley and Greeley counties, Nebraska.

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[28] Magoon, C. A.—"Sweet Corn Quality Due to Farm and Factory Influence." *U. S. Dept. Agr. Yearbook 1922,* p. 688.

Pop corn varieties are grouped into two general types, the rice with a pointed crown on the kernels, and the pearl, with a smooth rounded crown. The most important commercial varieties are the White Rice and the Japanese Hull-less, both of the rice type, though the Golden Queen, a yellow variety of the pearl type, is also well known. The White Rice is one of the largest pop corns with ears varying from 5 to 8 inches in length and covered with relatively large kernels. The Japanese Hull-less produces markedly short, thick, blunt ears with very deep, slender kernels. The Japanese Hull-less is of excellent quality and now constitutes the great bulk of the commercial crop. The White Rice is grown commercially for the manufacture of pop corn confections. The Golden Queen is a favorite in sections of the East and on the Pacific coast.

Varieties of pop corn have been developed in practically all colors common to field corn.

379. Moisture in Pop Corn and Popping Quality. Kernels of pop corn increase from 12 to 20 times in volume on popping. Various factors influence the volume of increase. Willier [29] concludes that a moisture content of 12 per cent is the optimum for greatest expansion in popping; that within a variety, kernels with the least soft starch expand the most, and that ears with the smaller kernels give the higher expansion in popping.

Stewart [30] states that pop corn with less than 12 or more than 16 per cent moisture does not pop well and that the best moisture content is between 13 and 15 per cent moisture.

At the North Dakota Station,[31] samples of corn with varying amounts of moisture were tested for popping quality. It was found that corn should have from 11 to 13.5 per cent moisture for best results. Too much moisture was found to be as detrimental as too little.

380. Manufactured Products.[32] As early as 1915 a total of 56,000,000 bushels of corn was used in the manufacture of starch, corn syrup, and sugar. Corn so used in 1919 amounted to 65,000,000 bushels and in 1924 to 75,000,000, while in 1927 it was 85,000,000 bushels.

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[29] Willier, J. G.—"Factors Affecting the Popping Quality of Pop Corn." *Jour. Agr. Res.* Vol. 35, No. 7, p. 624. 1927.

[30] Stewart, F. C.—"The Relation of the Moisture Content and Certain Other Factors to the Popping of Pop Corn." *N. Y. [Geneva] Agr. Expt. Sta. Bul. 505.* 1923.

[31] Yeager, A. F.—"Pop Corn Pointers." *N. Dak. Agr. Expt. Sta. Circ. 24.* 1924.

[32] *The Story of a Grain of Corn.* Associated Corn Products Manufacturers. Chicago, Illinois.

From this corn in an average year are made about 900,000,000 pounds of corn sugar; 1,065,000,000 pounds of corn syrup; 900,000,000 pounds of corn starch; 107,000,000 pounds of corn oil; and 685,000 tons of corn gluten feed, gluten meal and corn oil meal.

The process of manufacturing corn starch, corn syrup, corn oil, corn sugar, and products derived from these materials is based upon a most complete disintegration of the corn kernel into its various parts,—starch, protein, oil, and hull,—the one from the other. The corn, after being cleaned thoroughly, is run into large tanks where it is covered with water containing a small amount of sulfur dioxide. After the corn has been steeped, it is passed through mills which tear it apart without grinding it, liberating the germ, and separating the rest of the kernel. The torn corn is then mixed with enough water to float off the oil laden germ, which is cleaned and sent to the oil house.

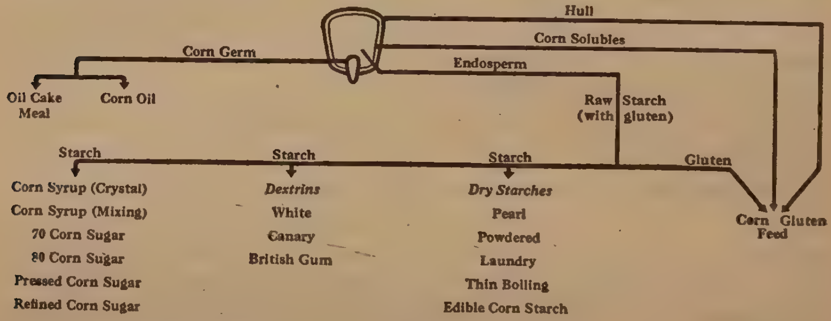
Hull
Corn Solubles
Corn Germ
Endosperm
Oil Cake Meal
Corn Oil
Raw Starch (with gluten)
Starch
Starch
Starch
Gluten
Corn Gluten Feed
Corn Syrup (Crystal)
Corn Syrup (Mixing)
70 Corn Sugar
80 Corn Sugar
Pressed Corn Sugar
Refined Corn Sugar
Dextrins
White
Canary
British Gum
Dry Starches
Pearl
Powdered
Laundry
Thin Boiling
Edible Corn Starch

FIG. 83.—The manufacture of corn products is based upon a most complete disintegration of the corn kernel and the separation of the various parts. The above outline suggests the different steps in the process. (From "The Story of a Grain of Corn.")

381. Corn Oil. The germ is dried in long, cylindrical, revolving driers, and is then crushed, cooked, and run through hydraulic presses or expellers which squeeze out the oil. Crude corn oil is used chiefly in the manufacture of refined oil for food, but it is also used in the manufacture of rubber substitutes. The refined oil is used by bakeries for shortening and as a cooking and salad oil in homes.

382. Corn Oil Cake or Meal. When the oil has been removed from the germ a residue remains which finds a market either as corn oil cake, or, when ground, as corn oil cake meal, a concentrated feed used for feeding hogs and cattle.

383. Starch. The remainder of the corn kernel after the germ has been separated is ground through stone mills which thoroughly disintegrate the harder portions of the corn and rub the starch from the hull. The hull is separated from the protein or gluten by means of reels or shakers covered with bolting cloth, through which the starch and gluten pass, while the hull remains. The mixture of gluten and starch, suspended in water, is then run onto the starch tables or starch runs, which consist of long, flat troughs about 8 inches deep and 100 feet in length with a very gentle slope so that the water runs slowly from one to the other, carrying with it the gluten but dropping the heavier starch. This starch builds up on the tables and finally the flow of gluten and starch is stopped and the starch remaining upon the table is then ready for removal to be used in the manufacture of dry starches. The starch is finally freed from as much water as possible and is then dried, after which it is placed in cartons or other containers and is ready for use as a food material of remarkable purity.

384. **Dextrins.** When dry starch is roasted, its proper tendency is to slowly change into dextrin. Raw starch is insoluble in water but when dextrinized it is soluble, giving an opaque solution.

385. **Corn Sirup.** The starch left on the tables or runs may be removed, mixed with water to form a heavy starch film, and weakly acidulated water added at high temperatures. This causes the starch to become hydrolyzed into glucose and maltose. Hydrochloric acid is usually used and the temperature of the starch-acid-water mixture is raised to about 280° F., after which the acidity is neutralized with soda so that no further change takes place. The resulting mixture is filtered through presses and over bone charcoal, and the liquid is finally concentrated to the desired density in vacuum pans. It is then cooled and put into packages as corn sirup. Corn sirup is extensively used in table sirups and candy making. The majority of table sirups are composed chiefly of corn sirup with enough sugar, molasses, sorghum, or maple sirup to give a more pronounced flavor than would be obtained from the corn product alone.

386. **Corn Sugar.** The change from the starch into the glucose or dextrose does not stop until about half the starch is changed into sugar, but if it is allowed to continue at a high temperature until practically all the starch is changed or converted into glucose a product is formed, which, after refining and concentrating in the same way as corn sirup, can be crystallized in much the same way as cane sugar is crystallized from the sugar sirup. This product is known as grain sugar, cereal sugar, bread sugar, hydro sugar, or corn sugar.

387. **Gluten Feed.** The gluten which was carried by the water when the starch was dropped on the starch runs is pumped to large filter presses, the plates of which are covered with cotton duck. Here

the enormous amount of water used in the different steps of the milling process is removed. The cake left in the process is removed and dried, the solubles which are removed by concentrating the steep water in vacuum pans being added during the process. The dry material is ready for the market as corn gluten feed.

The yield of the various products from a bushel of corn has been given by Allen [33] as 32.5 pounds of starch, 9 pounds of gluten meal, 7 pounds of corn bran, 2 pounds of germ oil meal, 4 pounds of water, and 1½ pounds of corn oil.

388. Other Products Manufactured from Corn. Alcohol can be made from corn,—a bushel of corn yielding about two and one-half gallons of alcohol. This may become an important industry as the commercial uses of alcohol are increasing rapidly. It is entirely possible that alcohol may become important in motive power. Furfural, made from corn cobs, is commercially important. A good grade of paper can be made from the pulp of ordinary corn stalks. A great variety of products have been made on a small scale from corn stalks and cobs in the chemical engineer's laboratory.

STUDY QUESTIONS ON CHAPTER XIII

1. Outline the probable development of corn. What characteristics of corn today point to such ancestry?
2. Contrast the method of corn production as practiced by the Indians with present-day methods. Indicate the practices which have been particularly improved upon.
3. Describe the growth and functioning of the corn plant. Tell why the roots fill the surface soil, why the leaves are not broken or frazzled in the wind, and the number of ears it is possible for a stalk to produce. Geographically, where is the tallest, and where is the shortest corn grown?
4. Describe the fertilization of the corn flower and answer the following questions as they fit into the description. What is the difference between fertilization and pollination? Why is it that pollen from a variety with red kernels when pollinating a white variety does not produce red kernels the first year? What are the chances of self-fertilization in a field of corn?
5. Distinguish the types of corn and differentiate between varieties and strains. What varieties of corn are used in your section?
6. Why does a variety of corn which is grown for a few years under different climatic conditions change materially in growth habit, while this is not true for oats?
7. Prepare a graph which will present the essential facts covering the utilization or disposition of the corn crop of the United States.

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[33] Allen, C. W.—*Industrial Fermentation*, pp. 170-171. New York Chemical Catalog, Inc. 1926.

APPLICATION ASSIGNMENTS ON CHAPTER XIII

1. Your field of yellow corn is joined by a neighbor's field of white corn. How can you be certain, in selecting your seed, that the corn is not mixed? Why?
2. Your farm is on the northern margin of the region adapted to corn production. What will be the characteristics of the corn you will grow?
3. You must buy seed corn and investigation shows that you may get seed of the variety you wish to grow from three sources: 75 miles north at $2.50 per bushel; 125 miles west for $3.00 per bushel, and 50 miles south for $2.00 per bushel. Which will you buy? Why?
4. Suppose you purchased seed from all three of the sources indicated above and grew it on your farm for a trial. What differences would you expect to note?
5. In harvesting a field of corn for silage when will you cut in order to secure the greatest production of digestible nutrients per acre?

CHAPTER XIV

SEED CORN

The proper selection and storage of an adequate supply of good seed corn have much to do with the prosperity of the corn belt. Good seed is dependent upon several factors, some of which have received a great deal of attention and are well understood, while others have been largely ignored.

389. Cost and Amount of Seed Required per Acre. Generally, in the corn belt, 1 bushel of seed corn can be expected to plant 7 acres. On this basis, when a man is willing to spend 50 cents a bushel for seed oats, making the cost of seed $1.50 per acre, an equal acre cost for corn would make a bushel of seed corn sell for $10.50. Seed corn commonly sells for $2.50 to $3.50 per bushel, although individual growers may obtain a price considerably above this because of a reputation for high yield, and if this corn is really superior the extra expenditure is well justified. The amount of seed corn required per acre varies somewhat with the variety. More seed is required with some of our large seeded varieties such as Hickory King than with smaller seeded types. Quesenberry[1] reports that of 15 varieties compared, using equal rates of planting, Busters Yellow Dent required the least, 7.7 pounds per acre, and Hickory King, the most, 15.2 pounds.

390. Methods of Picking Seed Corn. Seed corn may be saved in the field from the standing stalks before freezing weather by picking into a sack or into a special seed corn cart or sled which will pass between two rows, taking the best ears from 8 to 12 rows at a time. Seed corn is often picked at the regular husking time, the seed ears being thrown into a box on the side of the wagon or selected while unloading, while in some other sections much of the seed corn is picked later in the year from the bulk corn in the crib. The methods which can be used may depend somewhat on the location with reference to climatic conditions. In most parts of the corn belt there is real danger that freezing weather will injure the viability of the corn in the field before the crop can be harvested. Under such conditions some method of field selection of seed corn is usually best.

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[1] Quesenberry, George R.—"Corn Culture." *N. Mex. Agr. Expt. Sta. Bul. 132* 1922.

Even seed corn picked early from the field may be killed by a freeze before it has become sufficiently dry. The object of early field selection is to obtain a supply of viable seed from healthy, vigorous plants.

391. The Effect of Plant Environment on Yielding Ability of Seed. It has been suggested that a grower could probably obtain the most vigorous and high yielding seed by picking seed from corn grown under unfavorable conditions; as for example, planted thick so that the competition would be severe.

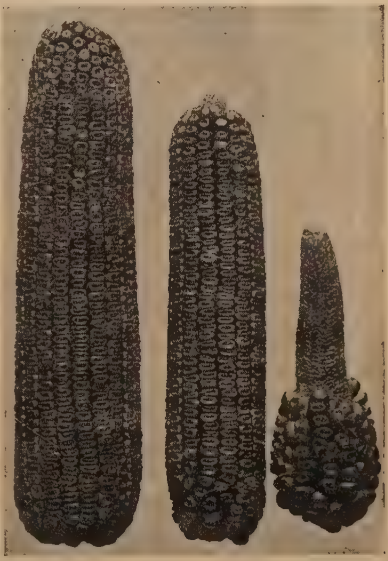

Fig. 84.—The product of a single hill of corn. *Was the difference in size and development of these ears due to differences in heredity or environment? What is the effect of the environment of the corn plant on the yield from the seed?*

Kiesselbach[2] planted plots with 1, 3 and 5 kernels per hill and later selected the better looking ears for seed from each of these. This was repeated year after year, planting the 1-kernel plot from seed selected on the 1-kernel plot and the 5-kernel plot with seed from the 5-kernel plot. This was continued from 1905 to 1923. At the end of 18 years the 1-kernel strain yielded 45.8 bushels; the 3-kernel strain yielded 46.7 bushels, and the 5-kernel strain, 47 bushels per acre when all were planted under uniform conditions with 3 kernels per hill.

Williams and Welton[3] report similar results in Ohio, where seed selected from 1-stalk hills when planted 3 kernels per hill yielded 63.9 bushels; seed from 3-kernel hills, 64.5 bushels; and that from 5-kernel hills, 64.3 bushels, as a 6-year average.

Another suggestion along this line was to select the larger, better ears for seed from corn grown on poor soil. Williams and Welton found in a study continued for 6 years that when grown under uniform soil conditions seed from corn grown on poor soil yielded 62.2 bushels, and that from corn grown on good soil, 62.3 bushels per acre. Fodder yields were 4026 pounds for the rich soil seed and 3902 for the poor soil seed.

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[2] Kiesselbach, T. A.—"Productive Seed Corn." *Nebr. Agr. Expt. Sta. Bul. 188.* 1923.

[3] Williams, C. G., and Welton, F. A.—"Corn Experiments." *Ohio Agr. Expt. Sta. Bul. 282.* 1915.

392. Effect of Freezing Temperatures on Germination. Kiesselbach and Ratcliff[4] exposed seed ears to different degrees of cold for a 24-hour period. The temperature was controlled by means of a brine solution flowing around the container in which the corn was placed.

392a. Temperature and germination of seed corn. Nebraska.

PER CENT[a] MOISTURE IN CORN	TEMPERATURE RANGES (DEGREES F.)				
	32 to 28	24 to 20	16 to 12	8 to 4	0 to −5
	Germination Per Cent	Germination Per Cent	Germination Per Cent	Germination Per Cent	Germination Per Cent
50 to 55	33	6	0	0	0
40 to 45	69	12	0	0	0
35 to 40	71	13	0	0	0
30 to 35	75	67	12	0	0
25 to 30	85	77	34	7	0
20 to 25	100	96	88	47	0
15 to 20	...	100	100	98	63
10 to 15	...	...	...	100	97

[a] Corn with over 60 per cent moisture did not germinate at all even at the highest temperature.

Corn was gathered from the field on October 30, 1913, after 9 days of freezing weather with the temperature continuously below the freezing point for 98 hours, with a minimum of 15° F. The ears, grouped according to moisture content, 10 to 15; 15 to 20; 20 to 25; 25 to 30; 30 to 35; and 35 to 40 per cent, germinated 100, 93, 43, 24, 3 and 0 per cent, respectively.

392b. Date of harvest and moisture content of seed ears as affecting germination. Nebraska.

CONDITION AND MATURITY ON OCTOBER 8	DATE SELECTED FROM FIELD					
	Oct. 8		Nov. 19		Jan. 17	
	Per Cent		Per Cent		Per Cent	
	Moist.	Germ.	Moist.	Germ.	Moist.	Germ.
Shocked corn fairly well matured	30	98	17	85	14	86
Standing in the field; well matured	35	98	17	83	14	88
Somewhat rubbery, ears twist.	39	94	21	56	17	61
Very rubbery, medium soft ...	43	92	26	34	19	20
Grain very soft	47	92	27	14	22	6
Late dough	50	82	34	10	27	0
Milk	63	44	36	1	28	0

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[4] Kiesselbach, T. A., and Ratcliff, J. A.—"Freezing Injury of Seed Corn." *Nebr. Agr. Expt. Sta. Res. Bul. 16.* 1920.

The Nebraska station also reports [5] the germination of corn which was in various stages of maturity when the plants were killed by frost October 8. The ears in different stages of maturity on October 8 were marked and left in the field until later dates. The first lot of ears was picked on October 8 after being exposed to 24° F.; a second lot on November 17 after being exposed to 17° F., and a third on January 17 after being exposed to —21° F. The per cent moisture and germination for each date and for each stage of maturity is given in Table *392b*.

393. Variations in Moisture Content at Picking Time. Kiesselbach [6] found that at Lincoln, Nebraska, on October 15 corn had 22 per cent moisture in 1911; 20 per cent in 1912; 17 per cent in 1913; 15 per cent in 1914; 35 per cent in 1915; 18 per cent in 1916; and 37 per cent in 1917.

Different kernels from the same ear may vary considerably in moisture content; in one case the most mature kernels from an ear had 49.2 per cent moisture, while the least mature had 64.4 per cent.

The rapidity with which corn may cure in the field will depend upon the weather conditions which prevail. In Iowa, in 1906, corn selected at weekly intervals throughout the fall had the following percentages of moisture: Sept. 14, 41.8 per cent; Sept. 21, 37.4 per cent; Sept. 28, 33.0 per cent; Oct. 5, 28.5 per cent; Oct. 12, 26.0 per cent; Oct. 19, 20.2 per cent; Oct. 26, 22.1 per cent; Nov. 2, 17.8 per cent.

394. Effect of Exposure on Yield from Viable Seed. Kiesselbach and Ratcliff [7] selected corn from the field on September 15, November 15, and March 15 which later was tested carefully for germination and planted in the field for yield comparisons. Four plots

394a. Yield in bushels per acre obtained from planting only those ears showing satisfactory germination, selected from seed harvested at different times. Nebraska.

DATE SELECTED	YEAR			AVERAGE
	1915	1916	1917	
September 15	66.6	36.1	38.3	47.0
November 15	65.9	37.3	41.6	48.3
March 15	64.7	42.1	42.6	49.8

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[5] Kiesselbach, T. A., and Ratcliff, J. A.—"Freezing Injury of Seed Corn." *Nebr. Agr. Expt. Sta. Bul. 163.* 1918.

[6] Kiesselbach, T. A., and Ratcliff, J. A.—"Freezing Injury of Seed Corn." *Nebr. Agr. Expt. Sta. Res. Bul. 16.* 1920.

[7] Kiesselbach, T. A., and Ratcliff, J. A.—"Freezing Injury of Seed Corn." *Nebr. Agr. Expt. Sta. Bul. 163.* 1918.

were planted with seed from each date of selection and the comparisons continued through three crop years.

395. The Cause of Death from Freezing. Kiesselbach and Ratcliff found that death from freezing is directly related to moisture content of the kernel and also to the duration of exposure to cold. Seed corn maturing in a natural way becomes cold resistant progressively as its moisture content diminishes, and its mortality increases as the duration of the killing temperature is extended. They state that the real cause of death from freezing of plant tissue is a difficult matter to determine, but that the most generally accepted theory is that water is withdrawn from the cells during the process of freezing and that this process continues until death results from the desiccation of the protoplasm. These investigators found the most satisfactory explanation in the theory that freezing produces a physical or chemical change aside from the withdrawing of the water from the protoplasmic or nuclear material of the cells.

396. Relative Value of Immature and Mature Seed. Kiesselbach[8] also reports the effect on yield and germination of very early picking of seed, before fully mature. All lots of seed were carefully cured.

396a. Effect of stage of maturity on germination and yield. Nebraska.

DATE OF SEED SELECTION	CONDITION OF GRAIN	NO. OF DAYS AFTER FERTILIZATION	PER CENT GERMINATION	TWO-YEAR AVERAGE YIELD, BU.
Sept. 1	Late milk	25	94	63.4
Sept. 8	Roasting ear	32	96	64.0
Sept. 15	Late roasting ear	39	97	63.0
Sept. 22	Denting	46	97	65.0
Sept. 29	Glazing	53	97	64.0
Oct. 6	Mature	60	98	64.5

The Illinois station reports[9] the stand in the field and the yield per acre obtained from seed picked at different stages of maturity. Seed picked at the glazed, dent, mature, and husking stage gave stands of 85, 86.2, 89.5 and 86 per cent, and yields of 49, 51.5, 53.8, and 50.8 bushels per acre.

Dungan[10] found that seed corn harvested before complete maturity absorbed water more rapidly and also possessed a greater water absorptive capacity than corn that had been allowed to mature on the stalks. He found that the more soft starch there was in the endosperm, the larger the amount of water imbibed by the kernel in the same variety of corn. Rapidity of water absorption was associated with quick germination, but seedling vigor more often accompanied horniness of the kernel and slow imbibition. Mature seed corn germinated slower but with more vigor than immature corn. Corn containing relatively large amounts of moisture during storage geminated quicker but with less vigor than corn with a small amount of moisture. Corn with 6.1 per cent of moisture showed a slightly lower vitality than corn with 12.6 per cent moisture.

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[8] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20*, p. 129. 1922.

[9] *Ill. Agr. Expt. Sta. Ann. Rpt. 40*, 1926-27.

[10] Dungan, George H.—"Some Factors Affecting the Water Absorption and Germination of Seed Corn." *Jour. Amer. Soc. Agron.* Vol. 16, No. 8, p. 481. Aug., 1924.

Carney [11] found that immature seed germinated quicker, although it did not maintain this advantage, developed more molds, and yielded slightly less than mature seed corn.

397. Variation Induced by Selection. Mass selection of seed ears is the oldest method of corn breeding. Nearly all of our commercial varieties were originated in this way. The effect of continuous selection for a particular characteristic in fixing this characteristic has been demonstrated in a good many experiments.

Work continued at the Illinois station, through a long period of years, is of particular interest. This work was begun by C. G. Hopkins in 1896 and has been continued to date. In reporting on this work Woodworth and Winter state [12] that after 30 years of selection the protein content of a "high protein" strain of corn has reached 18.17 per cent, while in a "low protein" strain it has fallen to 6.49 per cent. The oil content of a particular strain of corn has been raised by selection from 4.7 to 10.21, while in another strain it has been lowered to 1.43 per cent. One ear of 1926 crop had 0.69 per cent of oil. Similar selection for height of ear has produced one strain which in 1926 had an average height of ear of 108.9 inches and another strain from the same identical corn with ears averaging only 11.4 inches from the ground. The original percentage of two-eared stalks of 6.7 has been increased by selection to 47.8 per cent.

Woodworth [13] states that continuous selection for certain plant characters is probably more effective in corn than in any other crop, due to the fact that the corn plant is naturally cross-fertilized. He points out that it is continually producing hybrids which in turn cross among themselves, giving rise to a multitude of types through a recombination of characters. In a corn field a considerable array of different types are presented. Some of these are desirable because they are vigorous and productive, while others are equally undesirable because they are weak in stalk and roots, barren, or susceptible to disease. It is this great variation in the corn plant that furnishes an adequate basis for improvement.

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[11] Carney, Sidney Sylvester—"Seed Corn Investigations." *Ill. Agr. Expt. Sta. Thirty-seventh Ann. Rpt.*, pp. 49-50. 1923-24.

[12] Woodworth, C. M., and Winter, F. L.—"Field Crop Experiments in Illinois." *Ill. Agr. Expt. Sta. Ann. Rpt. 40*, p. 46. 1926-27.

[13] Woodworth, C. M.—"A Program of Corn Improvement." *Ill. Agr. Expt. Sta. Circ. 284.* 1924.

398. Plant Characters and Yield. Kiesselbach found,[14] in experiments continued over a 5-year period involving continuous selection for certain plant characters, that selection of single plant characters within a well adapted variety did not show any appreciable increase in yield except for down plants. Selection of seed for 5 years from plants which were down yielded 51.3 bushels, while ears from upright plants produced 56.9 bushels per acre.

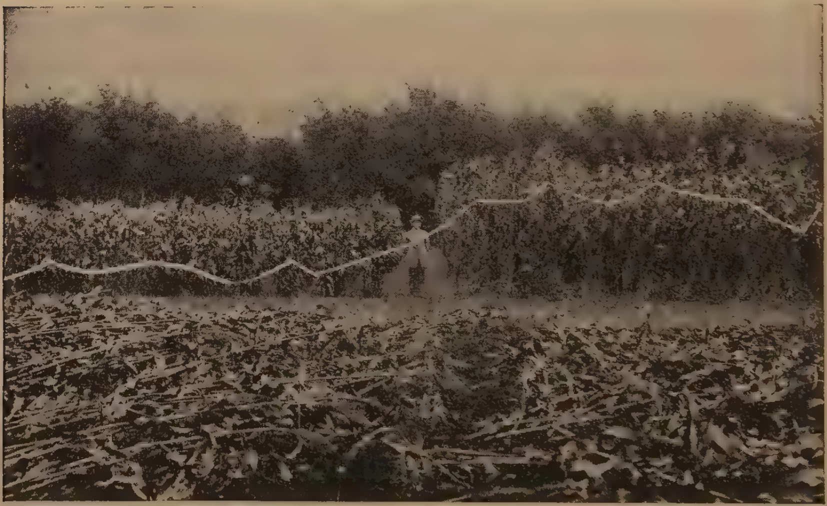

FIG. 85.—Two strains of corn developed from the same variety by rigid selection for high and low ears. The height of the ear on the front row of each plot is indicated. (Illinois Station.)

Kiesselbach[15] selected for erect ears and for drooping ears continuously for a 5-year period. Erect ears yielded 52.6 bushels; ears medium drooping, 52.5; and ears drooping, 54.9 bushels, while the original corn from which the selection was made yielded 55.3 bushels during the same period. The number of erect ears in that selected for erect ears was 42 per cent and in that selected for drooping ears 21 per cent.

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[14] Kiesselbach, T. A.—"Productive Seed Corn." *Nebr. Agr. Expt. Sta. Bul. 188*. 1923.

[15] Kiesselbach. T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20*, p. 120.

Williams and Welton[16] selected high and low ears during a 5-year period. The high-ear strain yielded 57.2 bushels of grain and 4434 pounds of stover; the low-ear strain 59.16 bushels of grain and 2866 pounds of stover. The low-ear strain yielded highest 4 years out of 5.

Kiesselbach reports[17] as a 5-year average that a high ear strain yielded 51.6; medium high, 53.1; and low, 53.6 bushels per acre. The medium ears outyielded the high ears 3 years out of 5. During this test the original Nebraska White Prize corn, from which the above selections were made, yielded 55.3 bushels.

Burlison and Dungan[18] report a 2-ear strain of Reid Yellow Dent, giving 109.4 per cent of the yield of the standard Reid Yellow Dent. The 2-ear strain, they state, will probably be found more useful for fodder or silage than for grain.

Ewing,[19] attempting to correlate various plant characters with the weight of grain per stalk, concluded that no single character showed itself so closely correlated with yield of grain as to be a safe guide for the breeder.

FIG. 86.—Picking seed ears from standing stalks in the field. *To what extent is it possible to influence the yield of corn by the selection of ears of a certain type or with certain characteristics? What are the best recommended practices to be observed in picking ears for seed?*

399. Disease and Seed Selection. Tiemann[20] studied the relation between the degree of indentation, the viability, and freedom from disease in seed corn, with the following results:

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[16] Williams, C. G., and Welton, F. A.—"Corn Experiments." *Ohio Agr. Expt. Sta. Bul. 282.* 1915.

[17] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res., Bul. 20*, p. 120. 1922.

[18] Burlison, W. L., and Dungan, George H.—"Field Crop Experiments." *Ill. Agr. Expt. Sta. Ann. Rpt. 38*, pp. 41-42. 1924-25.

[19] Ewing, E. C.—"Correlation of Characters in Corn." *New York [Cornell] Agr. Expt. Sta. Bul. 287.* 1910.

[20] Tiemann, O. P.—"Physical Characteristics of Disease-free Seed Corn." *Jour. Amer. Soc. Agron.* Vol. 16, No. 1, pp. 39-40. Jan., 1924.

Indentation	Average Viability	Percentage of Ears Testing Disease-Free
Rough	96.7	27.9
Medium rough	96.8	32.7
Medium smooth	97.1	42.7
Smooth	95.5	44.2

Tiemann also studied the relation of the luster to the viability and freedom from disease in seed corn, with the results as shown.

Color	Percentage Viability	Percentage of Ears Testing Disease-Free	Percentage of Ears Testing Badly Diseased
Very bright golden yellow	97.4	44.3	19.8
Bright golden yellow	96.9	38.7	28.4
Dull lemon yellow	96.9	30.9	32.8
Very dull lemon yellow	94.6	28.3	33.6

Tiemann states that the luster factor is also applicable to white seed corn, the pearly white being more desirable than the milky white kernels. He concludes that mature, firm seed ears of average size which show very bright color or luster, medium or smooth indentation, and fairly good depth of kernel should be selected for seed. These are characters which may be observed very easily and quickly.

Jehle *et al.*[21] found that, with other conditions similar, seed taken from cobs free of internal discoloration gave greater yields than seed from cobs with internal discoloration. The differences in yield vary with the intensity of the cob discoloration,—the slighter the discoloration, the greater the yield.

Winter[22] compared a number of strains of corn and found that each of the strains had a distinct average cob-breaking strength and that there was a positive relationship between this breaking strength and the yield. Either pink or red color of the ligneous part of the cob was also correlated positively with the yield. He found also that a negative correlation existed between brown coloration of the cobs of seed ears and yield.

Ear Characteristics and Seed Selection

Whether seed corn is picked from the stalk in the field or from the crib, the characteristics of the ear are given considerable attention by most corn growers. A number of the corn belt stations have studied the relation between the various characters and yield. A summary of all important previous work is included in the *Iowa Agrl. Expt. Sta. Bul. 257*, 1929. The studies at most of the stations compare different groups of seed ears, while the results reported from the Iowa station refer in the main to studies in which all ears produced on a given area of ground were included.

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[21] Jehle, R. A., *et al.*—"The Relation of Internal Cob Discoloration to Yield in Corn." *Md. Agr. Expt. Sta. Bul. 290.* 1927.

[22] Winter, F. L.—"Relation of Breaking Strength and Other Cob Characters to Yield of Corn." *Jour. Amer. Soc. Agron.* Vol. 18, No. 7, p. 595. July, 1926.

400. Length of Ear and Yield. In Table *400a* the average yields secured by planting long, medium, and short seed ears are reported for a number of stations.

400a. Length of seed ears and bushels per acre produced. Summary.

STATE	REFERENCE	NO. OF YEARS	BUSHELS		
			Long	Medium	Short
Iowa	a	3	45.2	43.9	41.7
Ohio (average of 4 varieties)	b	10	69.6	...	68.2
Ohio (Clarage corn)	b	8	63.41	...	62.94
Indiana	c	4	49.1	...	49.2
Kansas (9 varieties)	d	6	48.2	48.5	48.2
Nebraska (rough corn)	e	6	54.1	58.3	57.3
Nebraska (smooth corn)	e	6	59.1	58.3	57.1

[a] *Iowa Agr. Expt. Sta. Bul. 257.* 1929.
[b] *Ohio Agr. Expt. Sta. Bul. 282.* 1915.
[c] *Ind. Agr. Expt. Sta. Circ. 2.* 1910.
[d] *Jour. Amer. Soc. Agron.* Vol. *8*, p. 191. 1916.
[e] *Nebr. Agr. Expt. Sta. Res. Bul. 20*, p. 122. 1922.

Richey and Willier,[23] studying 3265 ears for correlation between a number of ear and kernel characters and yield, found that yield was related positively to length of ear.

401. Circumference of Ears and Yield. Hughes and Robinson[24] at the Iowa Station, considering all ears produced in the field, obtained the following yields per acre as an average for 3 years when these ears were used for seed: small, 41 bushels; medium small, 43.6 bushels; medium, 44.3 bushels; medium large, 44.4 bushels; large, 43.7 bushels per acre.

Cunningham,[25] at the Kansas Station, reports as an average for 9 varieties that ears large, medium, and small in circumference produced 47.9, 49.3, and 49.6 bushels per acre, respectively.

402. Shape of Ear and Yield. Several states report comparisons of the yield from ears selected for shape.

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[23] Richey, Frederick D., and Willier, J. G.—"A Statistical Study of the Relation between Seed Ear Characters and Productiveness in Corn." *U. S. Dept. Agr. Dept. Bul. 1321.* 1925.

[24] Hughes, H. D., and Robinson, Joe L.—"Relation of Certain Ear and Kernel Characters of Reid Yellow Dent Corn to Yield." *Iowa Agr. Expt. Sta. Bul. 257.* 1929.

[25] Cunningham, C. C.—"The Relation of Ear Characters of Corn to Yield." *Jour. Amer. Soc. Agron.* Vol. 8, No. 3, p. 192. May-June, 1916.

402a. Shape of ear and yield.—Summary.

Shape of Ear	Iowa Bul. 257 2-Year Average	Ohio Bul. 282 9-Year Average	Minn. Bul. 174 1 Year: Selected Ears
Tapering	47.7 bu.	68.3 bu.	24.2 bu.
Medium	47.1 "	...	...
Cylindrical	47.5 "	66.6 "	23.4 "

403. Size of the Seed Ear and Yield. Yields in bushels per acre, from planting large, heavy ears as compared with small, light ears are reported from Iowa and Minnesota in Table *403a.*

403a. Size of seed ears and yield per acre.

	Iowa Bul. 257	Minn. Bul. 174	
	Reid Yellow Dent, Bu.	Minn. 13, Bu.	Minn. 161, Bu.
Small ears	41.1	57.0	62.3
Medium small	41.9	...	...
Medium	44.2	58.4	62.1
Medium large	45.5	...	...
Large ears	45.5	57.9	62.6

404. Butt and Tip Formation and Yield. Yields from seed ears with poor, medium, and good butts and tips, as reported from Iowa, Kansas, and Minnesota are included in Table *404a.*

404a. Filling of the butts and tips with reference to ability to yield.

Type of Filling	Iowa Bul. 257	Kansas[a] Data 6 Yrs.	Minn. Bul. 174	
			Minn. 13	Minn. 161
Butts				
Poor	42.2	51.0	57.5	62.6
Medium	44.3	51.0	57.6	62.9
Good	43.4	50.7	57.4	62.0
Tips				
Poor	43.9	51.8	57.2	62.3
Medium	44.2	51.8	57.7	62.3
Good	44.3	51.7	57.5	62.9

[a] *Jour. Amer. Soc. Agron.* Vol. 8, No. 3, p. 193. May-June, 1916.

Williams and Welton[26] report an 8-year average of corn with poorly filled tips yielding 62.4 bushels and well filled tips yielding 62.8 bushels.

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[26] Williams, C. G., and Welton, F. A.—"Corn Experiments." *Ohio Agr. Expt. Sta. Bul. 282.* 1915.

405. Space between Rows of Kernels and Yield. Hughes and Robinson[27] report, as a 3-year average, rows close together at the crown of the kernel yielded 42.7 bushels; rows medium, 44.4; and rows with wide space, 45.6 bushels. In each of the 3 years the ranking was in the same order.

406. Shelling Per Cent and Yield. Williams and Welton[28] found seed ears with a high per cent of grain and deep kernels yielding 64.6 bushels, while ears with a low per cent of grain and shallow kernels yielded 65.1 bushels, as a 6-year average.

Cunningham[29] of Kansas found that ears with a high shelling per cent yielded 49.6 bushels; those with a low shelling per cent yielded 50.8 bushels.

407. Number of Rows of Kernels and Yield. Yields reported from Iowa and Ohio from planting ears with different numbers of rows are as shown in Table *407a*.

407a. The number of rows of kernels and yield.

No. of Rows of Kernels	Iowa Bul. 257	Ohio Bul. 282		
		Wooster	Germantown	Carpenter
	3-Yr. Average	5-Yr. Average		3-Yr. Average
14 and below	43.5	60.9	57.6	46.2
16	45.0	60.0	55.9	53.6
18	44.1	60.0	54.2	50.0
20	43.9	...	...	...
22	43.5	...	...	...
24	40.6	...	...	...

At the Kansas Station[30] seed selection in 5 varieties of 16, 18, and 20 rowed ears gave 43.6, 41.4, and 39.9 bushels, respectively, while in 2 other varieties 18, 20, and 22 rowed ears gave 59.3, 61.5, and 59.9 bushels per acre, respectively.

Richey and Willier,[31] in a statistical study, found in each of 4 varieties that those ears which had the smaller number of rows of kernels yielded best.

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[27] Hughes, H. D., and Robinson, J. L.—"Relation of Certain Ear and Kernel Characters of Reid Yellow Dent Corn to Yield." *Iowa Agr. Expt. Sta. Bul. 257.* 1929.

[28] Williams, C. G., and Welton, F. A.—"Corn Experiments." *Ohio Agr. Expt. Sta. Bul. 282.* 1915.

[29] Cunningham, C. C.—"The Relation of Ear Characters of Corn to Yield." *Jour. Amer. Soc. Agron.* Vol. 8, No. 3, p. 195. May-June, 1916.

[30] *Ibid.*

[31] Richey, Frederick D., and Willier, J. G.—"A Statistical Study of the Relation between Seed Ear Characters and Productiveness in Corn." *U. S. Dept. Agr. Dept. Bul. 1321.* 1925.

In Minnesota[32] the *Minnesota 13* with 12, 14, 16, 18, and 20 rows of kernels produced 55.1, 62.9, 66.1, 68.3, and 67.6 bushels per acre, respectively.

KERNEL CHARACTERS AND SEED SELECTION

As in the case of ear characters considerable experimental work has been done to determine the possible relation between various kernel characters and yield.

408. Indentation of the Kernel and Yield. The terms rough, medium, and smooth are all relative and no two persons will use exactly the same standards, so that ears classed as rough by one might be classed as only medium in indentation by another. There is considerable difference in the mean degree of roughness of indentation of different varieties and this must also be kept in mind.

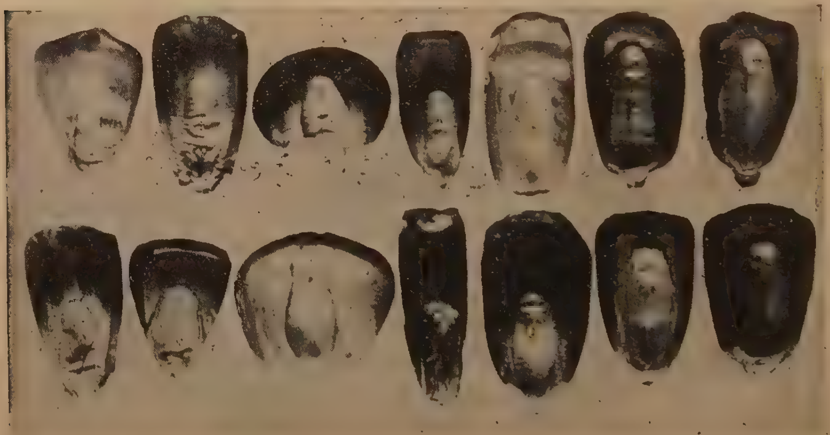

FIG. 87.—Characteristic corn kernels. *In examining seed ears what characteristics of the kernel may give some indication of the value of the ear for seed?*

408a. Kernel indentation and acre yield in bushels. Summary.

STATION	REFERENCE	NO. OF YEARS	SMOOTH	MEDIUM	ROUGH
Iowa	*Bul. 257*	3	45.08	43.8	43.7
Ohio	*Bul. 282*	7	65.30	...	63.6
Nebraska	*Res. Bul. 20*	6	59.10	...	54.1 Long
		6	57.10	...	57.3 Short
		2	69.60	...	64.0
		6	57.30	...	53.3
Minnesota	*Bul. 174*	1	21.40	21.9	20.6

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[32] Olson, P. J., *et al.*—"Ear Type Selection and Yield in Corn." *Minn. Agr. Expt. Sta. Bul. 174*, p. 47. 1918.

Cunningham[33] in 1916 reported work at the Kansas Station comparing rough, medium, and smooth ears of corn in each of 8 varieties with results as shown in Table *408b.*

408b. Indentation of seed ears and yield in bushels per acre. Kansas.

	ROUGH	MEDIUM	SMOOTH
Boone County White	43.0	49.9	47.6
Hildreth Yellow Dent	62.7	61.7	64.9
Reid Yellow Dent	61.7	65.1	67.4
Hogue Yellow Dent	36.4	38.2	40.4
Kansas Sunflower	43.7	43.2	45.9
Legal Tender	48.4	52.5	52.7
McAuley White Dent	51.2	55.1	57.4
Pride of Saline	35.4	40.0	40.9
Averages	49.2	52.6	53.5

409. Starchiness of Kernels and Yield. An excessive proportion of soft starch as seen on the backs and tips of kernels causes opaque, irregular shaped patches in the center and back of the kernel and crown. This condition may be hereditary or it may indicate immaturity. The horny starch is the semi-transparent flinty textured starch on either side of the kernel. **(513)**

Hughes and Robinson, working at the Iowa Station, compared starchy, medium, and horny kernels over a 3-year period, reporting in *Iowa Bulletin 257* the data shown in Table *409a.*

409a. Kernels with starchy, medium, and horny endosperm compared; yield in bushels per acre. Iowa.

CONDITION	YIELD
Starchy	41.7
Medium	44.1
Horny	46.0

In no case in this work did starchy ears yield as much as those classed as medium or horny. A total of 1276 mother ears was observed. The corn was Reid Yellow Dent.

Dungan[34] reports that seedlings produced from seed containing a relatively large amount of soft starch in the endosperm are not as vigorous as those from horny kernels. He states that this is because the floury starch is less rapidly hydrolyzed into a soluble condition than the horny starch. Horny corn contains as much starch as starchy corn of the same variety, and frequently, more; but the specific gravity of the starchy corn is considerably lower than that of horny corn.

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[33] Cunningham, C. C.—"The Relation of Ear Characters of Corn to Yield." *Jour. Amer. Soc. Agron.* Vol. 8, No. 3, p. 194. May-June, 1916.

[34] Dungan, George H.—"The Influence of Plant Injury and Root Rot Diseases upon the Physical and Chemical Composition of Corn Grain." *Ill. Agr. Expt. Sta. Bul. 284.* 1926.

410. Blistering of Kernels and Yield. Hughes and Robinson[35] classed 811 ears as badly blistered, medium bad, medium, medium free, and free of blistering. As a 2-year average these classes yielded 38.6, 42.1, 42.5, 43.2, and 46.7 bushels, respectively.

411. Other Kernel Character Studies. A number of other kernel characters were considered in yield studies at the Iowa Station continued through a 3-year period. As in the case of the ear character studies reported in *Iowa Bulletin 257*, every ear produced on a given area was included in the comparisons. Groups of kernels with the highest density produced 46 bushels per acre and with the lowest density 41.7. Kernels with plump tips 46.3 bushels and kernels with shrunken tips 41.5. The Iowa studies indicated that with this particular strain of corn ears with the larger, deeper, and thicker kernels were most productive.

412. Butt, Middle, and Tip Kernels. In preparing seed for planting a portion of the tip and the butt kernels of each ear is usually shelled off and discarded. Relative yield of butt and tip kernels when the yield of the middle kernels is taken as 100 is given in the following table as summarized from a number of stations.

412a. Relative yields of butt, middle and tip kernels in corn. Summary.

STATION	NO. YEARS	NO. TESTS	RELATIVE YIELDS		
			Butts	Middles	Tips
Alabama	1	3	117	100	106
Alabama	3	3	103	100	104
Arkansas	1	1	111	100	99
Georgia	3	3	106	100	108
Georgia	1	1	102	100	104
Kansas	5	15	109	100	111
Ohio	10	10	102	100	101
Ontario	1	1	104	100	102
Penn. Central	4	4	98	100	102
Western	4	4	97	100	101
New York	4	32	99.8	100	103
Wisconsin	3	3	100	100	101
Tennessee	1	1	123	100	95
Nebraska	6		98.5	100	100.3

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[35] Hughes, H. D., and Robinson, J. L.—"Relation of Certain Ear and Kernel Characters of Reid Yellow Dent Corn to Yield." *Ia. Agr. Expt. Sta. Bul. 257*, p. 192. 1929.

413. Seed Selection for Yield Based on Visible Ear and Kernel Characters. At the Iowa Station[36] 500 ears of corn, including every ear produced on a given area, whether large or small, were divided into 10 groups by 12 individuals, all experienced in seed corn. The average yield of corn produced by these groups of ears when planted was, from best to poorest, as follows: 49.1, 48.0, 47.5, 47.8, 47.5, 47.0, 46.6, 45.8, and 44.0 bushels per acre.

Wallace[37] determined the correlation between the scores of the corn judges and the yield of the crop, and found the correlation to be only 0.2.

414. Summary of Ear and Kernel Characters as Related to Yield. Richey[38] reports a summary of studies on the relation of certain ear characters and yield. Only the totals for each character are reported in the table below.

414a. Ear and kernel characters in relation to yield. Summary.

SEED EAR CHARACTER	TOTAL COMPARISONS	NUMBER OF TIMES RESULT WAS IN FAVOR OF EARS POSSESSING THE CHARACTER TO THE DEGREE STATED		
		Large Degree	Medium Degree	Small Degree
Weight	39	35	..	3
Length	56	43	3	10
Circumference	22	10	4	8
Shelling percentage..	40	11	..	29
Number of rows	59	19	14	26
Indentation[a]	16	3	2	11

[a] Rough is "large degree"; smooth, "small degree."

Kiesselbach[39] states that a review of the available data indicates that within reasonable limits the variations in ear characters are neutral in their effect upon the yield of dent corn, except as they are linked with special adaptive growth characteristics of the plant; thus slender ears with smooth, shallow kernels tend to produce earlier maturing, smaller, and less rank growing stalks than large, rough, deep kerneled ears of the same variety. There are indications that strict type selection, if long continued, may even reduce productivity through an approach toward gametic purity for the selected characters.

[36] Hughes, H. D., and Robinson, J. L.—"Relation of Certain Ear and Kernel Characters of Reid Yellow Dent Corn to Yield." *Ia. Agr. Expt. Sta. Bul. 257*, p. 202. 1929.

[37] Wallace, H. A.—"What Is in the Corn Judge's Mind?" *Jour. Amer. Soc. Agron.* Vol. 15, No. 7, pp. 300-304. July, 1923.

[38] Richey, Frederick D.—"The Experimental Basis for the Present Status of Corn Breeding." *Jour. Amer. Soc. Agron.* Vol. 14, Nos. 1 and 2, p. 3. Jan.-Feb., 1922.

[39] Kiesselbach, T. A.—"Ear Type Selection and Yield of Dent Corn." *Jour. Amer. Soc. Agron.* Vol. 14, Nos. 1 and 2, p. 47. Jan.-Feb., 1922.

It is well to recognize the fact that there is a marked relationship between some of the different ear and kernel characters and that the particular character observed in the above study reported actually may be either relatively more or less important than the yield data would indicate. For example, indentation may be expected to be associated with number of rows; number of rows with space between the rows; space between the rows with starchiness; starchiness with density; size of kernel with depth and thickness, etc.

415. Storage and Germination. The conditions under which seed ears are cured and stored may have an important influence on yield.

Wisconsin[40] reports the average germination of seed corn stored under ten different conditions for 1909, and 1910.

415a. Storing seed corn as it affects germination in Wisconsin.

	Germination		No. of Tests
	1909	1910	
1. Kiln dried	93	90	16
2. Furnace room	93	89	8
3. Room above the kitchen	92	81	112
4. In attic	92	77	75
5. Under porch	79	62	27
6. In granaries	65	43	20
7. In barns or tool sheds	86	52	52
8. Corn cribs	38	37	26
9. In shocks	81	1.5	4
10. Windmills and outside walls of buildings	45	23	10

In the fall of 1915, which was unfavorable for the curing of seed corn, Hughes and Stanfield[41] picked seed corn at weekly intervals for 11 weeks and stored it under different conditions. The results are shown in Table *415b*.

415b. Method of storing seed as influencing germination. Iowa.

Maturity of Seed Ears When Picked	Condition of Storage	No. of Lots Tested	Per Cent of Seed Ears Testing Strong
Mature	Seed house, heated	11	74
	Closed shed, not heated	11	35
	Open shed, not heated	11	11
Immature	Seed house, heated	11	54
	Closed shed, not heated	11	14
	Open shed, not heated	11	10

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[40] Norgord, C. P.—"Crop Demonstrations on State and County Farms." *Wis. Agr. Expt. Sta. Bul. 208.* 1911.

[41] Hughes, H. D., and Stanfield, W. W.—"Seed Corn for the 1916 Crop." *Ia. Agr. Expt. Sta. Circ. 28.* 1916.

The germinations reported are averages in all cases of seed selected through an 11-week period, with more or less of the seed injured before being placed in storage.

When artificial heat was used in the closed shed until January 1 with no heat later, 73 per cent of the mature and 57 per cent of the immature ears tested strong in germination. When no artificial heat was used at any time, 35 per cent of the mature and 14 per cent of the immature ears germinated strong.

Ohio[42] reports a test of the germination and yield of seed corn when stored in various places.

415c. Method of seed storage as influencing yield. Ohio.

Method of Storage	5-Yr. Av. Germ.	5-Yr. Av. Yield	Germ. 1918 (1917 Corn)
1. On rack on second floor of corn crib	96.3	72.6	9.0
2. In slatted box buried in crib corn ...	89.4	71.0	1.0
3. On rack in warm room	97.2	73.5	93.7
4. In furnace room, hung up	97.5	75.1	95.7
5. Buried in oats bin	92.8	71.2	85.8

416. Method of Handling Seed in Storage. The important consideration in handling seed ears is to provide a good circulation of dry air around each ear so that drying may be rapid and still handle the ears with as little work as possible. Special seed corn racks and wire hangers may be purchased for hanging seed corn. The twine hanger is a hanger in which a double loop of twine is used, the ends being crossed between the placing of each ear in the hanger. A convenient method of hanging seed ears is on hangers made from electric welded fence wire, cut so that each hanger holds from 20 to 30 ears. Seed corn racks are often built and the ears laid on the racks. Sometimes posts are used in which nails are driven and the ears pushed down over the ends of these nails. Any device which is reasonably cheap and convenient, and yet gives good ventilation to each ear is satisfactory. Many seedsmen, particularly those specializing in seed corn, use artificial heat to dry the seed corn soon after it is picked. This practice will no doubt become much more general owing to the better germination secured and the freedom of such seed from disease. Corn is usually placed in a bin with ventilating devices or in a room on trucks or drying racks and heated air forced through. The temperature used for drying should be between 100 and 120 degrees Fahrenheit. If the heat goes over 120 degrees, severe injury is likely to result. For small quantities of seed corn, some form of hanger usually is most satisfactory.

[42] Welton, F. A.—"Storage of Seed Corn." *Ohio Agr. Expt. Sta. Monthly Bul.* Vol. 3, No. 12. p. 361. Dec., 1918.

417. Effect of Combustion Fumes on the Germination of Seed. Seed growers are interested in the possibility of using the fumes from oil-burning furnaces in the drying of seed, as this makes possible the full utilization of the fuel. Morgan Bros., Galva, Illinois, in the fall of 1927 conducted extensive trials to determine the effect of combustion gases on the vitality of the seed. The different lots of corn contained from 36 to 43 per cent of moisture. The drying periods varied from 117 to 286 hours and the temperatures from 75 to 110 degrees F. When the seed was subjected to pure combustion gases, with the conditions as indicated, the vitality was seriously injured.

FIG. 88.—*In the drying and storage of seed corn what factors are most important in securing the best seed that can be produced?*

The germination was not injured when an admixture, estimated at 50 per cent combustion gases and 50 per cent air, was used. This is believed to approximate the admixture delivered from forced draft oil-burning furnaces.

Soybean seed dried 26 and 59 hours at temperatures ranging from 85 to 115 degrees F. was considerably injured when 50 per cent of combustion gases was used.

418. Testing Seed Corn for Germination. Hughes[43] compared thirteen methods of germinating seed corn. He concluded that no particular method was decidedly better than other methods in picking out particularly high yielding seed. He also concluded that testing seed under favorable conditions gave a satisfactory measure of its relative value when planted in the field. When ears which showed no weak kernels in the germination test were arranged according to the number germinating out of six tested, the stands and yield were as shown in Table *418a*.

The decrease in stand and yield from planting seed ears with kernels recorded as weak in germination was found to be as shown in Table *418b*.

Williams and Welton[44] report a 4-year comparison of ear tested

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[43] Hughes, H. D.—"The Germination Test of Seed Corn." *Ia. Agr. Expt. Sta. Bul. 135.* 1913.

[44] Williams, C. G., and Welton, F. A.—"Corn Experiments." *Ohio Agr. Expt. Sta. Bul.* 282. 1915.

418a. Field stand and yield when ears are grouped according to the number of kernels germinating out of six tested. Iowa.

Total Number of Ear Readings	Germination		Per Cent of Stand in Field	Yield Bu. per Acre
	Strong	Dead		
769	6	0	72.3	75.1
472	5	1	58.5	65.4
425	4	2	52.4	58.6
347	3	3	41.5	50.1
340	2	4	34.1	42.1
297	1	5	27.7	39.4
259	0	6	26.6	34.7

418b. Field stand and yield when ears are grouped according to the number of kernels germinating "weak" out of six tested. Iowa.

Germination	Number of Ear Tests	Per Cent Stand	Yield in Bushels per Acre
6-0-0	6134	73.3	55.5
5-1-0	1899	68.3	52.8
4-2-0	1236	66.7	52.3
3-3-0	733	66.3	50.0
2-4-0	504	63.0	49.9
1-5-0	257	65.5	51.4
0-6-0	234	69.5	53.5

and of untested seed corn. Untested seed germinated 88.6 per cent, making 76.2 per cent stand in the field and yielded 55.4 bushels. Tested seed corn germinated 100 per cent and made 85.6 per cent stand and yielded 59.3 bushels per acre.

419. Methods of Individual Ear Testing. The "rag doll" method of making individual ear tests was recommended by the Iowa Station in 1913 [45] after making 45,000 individual ear tests comparing 13 different methods. This method rapidly came into general use and is the one most commonly used where corn is grown.

The rag doll. In using this device for individual ear testing corn, a strip of muslin about eight or ten inches wide and three or four feet long is marked into squares by first penciling a line down the center and then cross lines every three inches. After numbering the squares (or every fifth or every tenth square) the muslin is first soaked in water and then spread out smooth on a board of convenient size. From each ear to be tested, 6 kernels are taken and placed in one of the squares, and the ear numbered to correspond with the number of the square. When the squares have all been filled, the cloth

[45] Hughes, H. D.—"The Germination Test of Seed Corn." *Iowa Agr. Expt. Sta. Bul. 135.* 1913.

is rolled up and tied loosely or, still better, held with a rubber band. The "doll" is then soaked in water for from 2 to 10 hours, placed in a pail or other container, covered so that it will keep moist, and kept at a little above room temperature for from 5 to 8 days. At the end of this time the test is ready to "read."

420. Vigor of Growth and Yield. Hughes[46] found that seed ears which gave the most rapid early growth in the field produced the best yields. Planted in the field, horny kernels made a more rapid early growth than did starchy kernels and outyielded starchy kernels by about 4 bushels per acre.

Seed classed as "slow" and "rapid" in germinating[47] were tested over a period of 5 years at the Pennsylvania station. Slowly germinating seed yielded 74.5 bushels, while rapidly germinating seed yielded 73.0 bushels. Slowly germinating seed yielded highest three years, and the rapidly germinating seed, two years.

Ohio[48] reports tests in which 600 ears of corn were tested in the germinating box and classed according to "first up" and "last up." Plots planted with "first up" kernels yielded 65.18 bushels, while those planted with "last up" kernels yielded 68.03 bushels. They state that the first kernels to come up were the soft kernels which absorbed water readily. Those coming up last were more dense kernels.

It seems apparent that while the starchy kernels germinate more quickly, the horny kernels produce the more vigorous growth when planted in the field.

421. Number of Seminal Roots and Yield. Smith and Walworth[49] noted that there was a great variation in the number of secondary or seminal roots produced in different seedlings, that individual ears showed characteristic tendencies in this respect, and that varietal differences were also noticeable. Their data show a positive correlation between high seminal root production and yield of crop; and they conclude that high seminal root production probably tends to enhance the vigor of early growth.

422. Per Cent Stand and Yield. The effect of less than a perfect stand on the yield was determined in Iowa on 39 county demonstration plots during a 7-year period. The average of all comparisons is summarized in Table *422a*.

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[46] Hughes, H. D.—"The Germination Test of Seed Corn." *Iowa Agr. Expt. Sta. Bul. 135*, p. 363. 1913.

[47] Noll, Charles F.—"Experiments with Corn." *Pa. Agr. Expt. Sta. Bul. 139.* 1916.

[48] Williams, C. G., and Welton, F. A.—"Corn Judging: Studies of Prominent Ear Characters in Their Relation to Yield." *Ohio Agr. Expt. Sta. Bul. 212.* 1909.

[49] Smith, L. H., and Walworth, E. H.—"Seminal Root Development in Corn in Relation to Vigor of Early Growth and Yield of Crop." *Jour. Amer. Soc. Agron.* Vol. 18, No. 12, p. 1120. Dec., 1926.

422a. Yield of corn as related to per cent of a three-stalk per hill stand. Iowa.

Per Cent Stand	Per Cent Yield	Per Cent Stand	Per Cent Yield
50	67.3	75	88.3
55	71.6	80	91.9
60	76.2	85	95.5
65	80.8	90	97.0
70	84.6	95	98.6
75	88.3	100	100.0

423. Uniformity of Stand as Related to Yield. The relation of the uniformity of the stand to the yield is indicated from work at the Nebraska station[50] continued through a 5-year period; yields are given in bushels per acre:

1. All hills planted uniformly 3 plants, 59.0.
2. Alternating 2 and 4 plants per hill, 59.2.
3. Alternating 1, 3, and 5 plants per hill, 56.1.
4. Alternating 1, 2, 3, 4, and 5 plants per hill, 58.6.

424. Uniformity of Stand from Thickly Planted, Low Germinating Seed. It is sometimes necessary to use as seed, corn of low vitality, planting thick. Kiesselbach reports[51] the distribution likely to follow the use of seed corn that germinates 75 and 65 per cent when planted 4 kernels per hill.

424a. Stand from low vitality seed planted thick. Nebraska.

Number and Viability of Kernels	Number of Hills in Each Group with	
	65 Per Cent Viable Seed	75 Per Cent Viable Seed
4 Viable	578	1024
3 Viable, 1 dead	1246	1370
2 Viable, 2 dead	1007	684
1 Viable, 3 dead	361	151
4 dead	49	12

425. Effect of Grading Seed on Planter Drop. Indiana[52] determined the number of times out of each 100 drops that 1, 2, 3, 4, 5, and 6 kernels were found per hill, when the planter was set to plant 3. The results are given in Table *425a.*

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[50] Kiesselbach, T. A.—"Productive Seed Corn." *Nebr. Agr. Expt. Sta. Bul. 188.* 1923.

[51] Kiesselbach, T. A.—"Productive Seed Corn." *Nebr. Agr. Expt. Sta. Bul. 188,* p. 29. 1923.

[52] Wiancko, A. T.—"Corn Improvement." *Ind. Agr. Expt. Sta. Bul. 110.* 1906.

425a. Number of kernels dropped per hill with different classes of seed used. Indiana.

No. of Kernels Dropped	Kind of Seed Used				
	Kernels from Middle of Ear Only	Whole Ear	Deep and Shallow Kernels Mixed	Deep Kernels Only	Shallow Kernels Only
1	....	1 time	....	....	2 times
2	8 times	6 times	5 times	4 times	2 times
3	92 times	66 times	75 times	92 times	95 times
4	....	25 times	18 times	4 times	1 time
5	....	1 time	2 times	....	....
6	....	1 time	....	....	....

426. Uniformity of Drop Influenced by the Type of Planter. The Nebraska Station[53] compared four types of planters as follows:

No. 1 used an edge selection, intermittent moving plate.
No. 2 used an edge selection, continuous accumulative plate.
No. 3 used a round hole, full hill, intermittent plate.
No. 4 used a round hole accumulative plate.

Using butted and tipped, hand graded, medium kernels the number dropped per hill, with the planters set for three is indicated in Table *426a.*

426a. Type of planter and uniformity of drop. Four different types of planters compared for uniformity of drop as measured by the per cent of hills with different numbers of kernels. Nebraska.

Planter No.	Per Cent of Hills Having Stated Number of Kernels							
	0 Ker.	1 Ker.	2 Ker.	3 Ker.	4 Ker.	5 Ker.	6 Ker.	7 Ker.
1	...	1.2	15.4	63.6	17.7	2.1	...	...
2	...	0.1	6.5	69.1	21.7	2.6	...	...
3	0.1	0.2	6.9	52.8	36.4	3.4	0.2	...
4	0.1	4.0	22.8	57.2	15.1	1.7	...	0.1

STUDY QUESTIONS ON CHAPTER XIV

1. You are to provide seed corn for a 40-acre field. Outline and discuss the following points: (1) Amount to pick. Why? (2) Method of picking. Why? (3) Time to pick. Why? (4) Conditions which may result in injury to seed corn and how the injury is brought about.
2. List the essentials of a satisfactory storage place for seed corn and tell why each is necessary.

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[53] Chase, L. W., and Chase, C. F.—"Tests of Corn Planters with Graded Corn." *Nebr. Agr. Expt. Sta. Ann. Rpt. 25*, p. 119. 1912.

3. Is it practical to dry seed corn artifically? If so, how would you do it?
4. You decide to select your seed corn from standing stalks in the field. Describe the stalk characters to be observed. When will you make the selection?
5. Write a description of the ear you will select for seed. Will you select for a uniform type? Why?
6. Describe the kernel characters which you consider most desirable. Why?
7. In general, is it advisable to have in mind a particular type of ear and of kernel and keep close to this type? Why?
8. Is it necessary to make a germination test of carefully picked seed corn in the spring before planting? Why?
9. Explain the results obtained in a comparison of rapidly and slowly germinating corn.
10. Give instructions for the preparation of ear corn for planting, explaining the reason for each operation.

APPLICATION ASSIGNMENTS ON CHAPTER XIV

1. July and August have been cool and wet. You are considering the picking of seed corn in the field but are thinking of letting it go until harvest, as you have observed that for the last three years your neighbor, who has picked from the elevator, has had as good germinating seed as yours. Give the considerations involved in making a decision. Which will you do? Why?
2. In picking seed corn in the field you observe a medium height stalk on which the leaves are all brown. This stalk bears one large drooping ear, apparently solid and mature. In the same hill are two green stalks like others in surrounding hills. Will you pick the ear from the stalk first mentioned?
3. In picking seed you find a three-stalk hill of corn surrounded by full hills. In this hill is one stalk with two solid, mature ears, longer than average, and slightly smaller in diameter. Another stalk has one large sound ear, large in diameter. A third stalk bears one rather small ear and a nubbin. What ears will you pick for seed from this hill? Why?
4. You have two ears of corn picked for seed. One has a rectangular kernel, horny, inclined to be smooth in indentation, medium shallow, plump at the tip. The other has a deep, keystone-shaped kernel with a streak of soft starch down the back and a triangle of soft starch at the tip. Which one, if either, will you plant? Why?
5. You have an ear of good general appearance with plump kernel tips. The tip caps break off when shelled and the shank is brown and shredded. Will you keep the ear for seed? Why?
6. Frost has checked the growth of corn in the field before you have picked your seed. The corn is still soft and freezing weather has been predicted. What will you do? Why?

7. Two men entered their corn in a yield test. The corn was originally of the same strain. One had practiced careful stalk and ear selection; the other used only crib selection. In the yield test the crib selected corn yielded highest for three consecutive years. The farmer who has practiced careful selection wants to know why? Write a letter to him telling how this could be possible.
8. When you go into the seed house in the spring you notice the mice have chewed the crowns off many of the kernels on one-third of the ears. How will you prepare this seed for planting?
9. You have purchased 100 ears of a high yielding strain of corn, paying 25 cents per ear for it. What will you do in order to get the greatest return from this seed?

CHAPTER XV

CORN IMPROVEMENT

It is not the purpose of the authors to introduce here a well-rounded discussion on corn breeding but to bring to the attention of those interested in corn and corn improvement some information which, it is believed, will aid in answering some of the more common questions arising in a corn improvement program. In addition to the discussion of some of the more simple fundamental questions in corn breeding, the methods which have been employed in corn improvement will be outlined briefly and some of the results presented.

Since corn is cross-pollinated, breeding work with this crop is somewhat more difficult than with the small grains, which, in most cases, are normally self-pollinated. The female parentage of an ear of corn can be known, but unless pollination is controlled by covering the silks and introducing only the pollen desired, the male contribution is always uncertain and geneticists and breeders have shown that the male parent has as much influence on the progeny, or offspring, as the female.

Some Principles of Inheritance

427. Color in the Corn Kernel. Beginning at the outside of the corn kernel there is a thin layer of material making up what is known as the seed coat or pericarp, and immediately under this is a single layer of cells called the aleurone layer. Inside this aleurone layer and consisting of relatively large, loose starch cells is the endosperm which makes up most of the kernel and surrounds the scutellum. Within the scutellum is the embryo or miniature plant.

The pericarp or hull usually is either red or colorless, but occasionally it is striped either red or yellow. Corn of such colors is commonly referred to as calico. As the seed coat is a part of the mother plant and is the result of the fertilization of the preceding year, its color is not affected by the pollination which results in the development of the individual kernel. On the other hand, the endosperm and aleurone are a part of the young embryo plant and take their color from the union of the pollen and the egg cell. The color of the endosperm, then, is independent of the seed coat and aleurone colors. It would be possible to have either white or yellow endosperm overlaid by either red or colorless seed coat, or by purple, red, or colorless aleurone. The aleurone may be colorless, purple, bluish black, or red. Endosperm colors range from orange-yellow to white, with all gradations of yellow intervening.

To illustrate the principle of inheritance: let us assume that a pure ear of Silver King, or of any other white corn which has white pericarp and white endosperm, is pollinated by Cardinal King, which has a red pericarp and white endosperm. In the year the cross is made the Silver King will still be white, since the only character carrying color is the pericarp, which is mother tissue. The next year, when seed from this cross-pollinated ear is planted, all of the progeny at harvest time will have red ears like the Cardinal King corn. The red color is said to be dominant in inheritance to white in this case. If the next year these hybrid red ears are planted, the progeny will have about 3 red to 1 white-eared plants. If these plants are self-pollinated and seed planted from each of the ears the next year, it will be found that the white plant was pure white, while 2 of the red plants were hybrid and 1 pure red, giving only red plants. The two hybrids again show the proportion of 3 red to 1 white.

428. Mixtures in Corn. Yellow corn often becomes contaminated with pollen from white corn, and the kernels may show very pale yellow or even white kernels. Such a contamination is very difficult to eliminate. The white color is recessive to yellow and the contamination will remain a long while, although the use of only deep yellow seed ears for planting may gradually lower the amount. When the contamination is the reverse,—that is, white kernels pollinated from yellow corn,—the yellow may be eliminated by planting only pure white kernels. The difficulty is entirely in the case of very light yellow kernels which are hybrid but do not show up as plainly as the others.

When field corn becomes contaminated with pollen from sweet corn, it is very difficult to eradicate the sweet corn since the field corn kernels hide the sweet corn mixture. If contamination is in the opposite manner,—that is, if the field corn is the pollen parent and only sweet corn kernels are planted, the resulting crop should be pure sweet corn. In the case of a mixture of red and white corn with the red color carried by the mother plant, the ear will be red; while if the mother plant is a white corn, even though fertilized by red, the kernels produced will be white. For this reason such contamination is very difficult to eradicate and even in white or yellow corn completely red ears will occasionally crop out.

429. Mendel's Law. Mendel's law is based on the following facts: (1) Male and female plants contribute equally to their offspring. (2) Characters go in pairs, one member of each pair commonly being dominant or partially dominant and the other member recessive. (3) A plant hybrid for a pair of characters contains the recessive member of the pair as well as the dominant member although it is hidden from view. (4) The hybrid plant produces two kinds of germ cells (eggs or pollen) in equal numbers, one-half containing the dominant and the other half the recessive character. When pollination takes place there is an equal chance of each kind of pollen fertilizing each of the two kinds of eggs. Lindstrom[1] has illustrated this scheme in a chart showing the crossing of a red variety and a white variety.

Parents	Red Variety RR Eggs All R	x	White Variety WW Pollen All W
First Hybrid Generation	All RW Eggs 50% R 50% W		Hybrid Red Pollen 50% R Pollen 50% W

Second Hybrid Generation (Produced by self-pollinated red-hybrids)

1 R R—25% pure red (like pure red variety)

$$\left.\begin{array}{l}1\ \mathrm{R}\ \mathrm{W}—\\1\ \mathrm{W}\ \mathrm{R}—\end{array}\right\}\ \text{50\% hybrid red (like first hybrid generation)}$$

1 W W—25% pure white (like pure white variety)

This simple illustration of inheritance applies equally to plants and animals. All inheritance is not as simple as this, but this system underlies the more complex breeding.

430. Number of Rows of Kernels. The number of rows of kernels on an ear of corn varies from 8 to about 26. The 8-row type is characteristic of the flint and some of the sweet corns, while a greater number of rows is found on the larger dent and larger sweet varieties. In most varieties the number of rows of kernels will be found to vary considerably on different ears, though the flints do not tend to vary so widely.

In Country Gentleman sweet corn the kernels do not appear to be arranged in rows. This can be accounted for, as well as the pairing of rows in ordinary corn, by the fact that botanically the ear is a fused group of branches, each bearing a series of paired spikelets along its full length, each spikelet having two flowers. One of the two flowers in each spikelet has degenerated or become sterile, leaving only one to grow and form the grain. As the spikelets are paired an even number of rows of grain results. In the Country Gentleman variety both flowers are fertile in most of the spikelets; both develop kernels and accordingly the kernels become crowded and irregularly arranged on the cob.

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[1] Lindstrom, E. W.—"Corn Breeding." *Wis. Agr. Expt. Sta. Bul. 356*. 1923.

THE POLLINATION FACTOR

431. The Effect of Cross-Pollination on the Immediate Yield. It is evident from the preceding paragraphs that the character of the pollen which falls on the silk and brings about the fertilization of the flower can influence the yield of the resulting crop only in so far as it may influence the size or weight of the individual kernels produced. Kiesselbach [2] states that the cross-pollination which takes place when different commercial varieties similar in endosperm type are grown side by side has no significant effect on the relative yields of the different varieties.

Smith [3] concluded that the relative yields of corn varieties grown side by side ordinarily were not seriously affected by cross-pollination, but that sweet corn varieties should be tested in the absence of pollen from dent corn.

Collins [4] has reported that an ear of Chinese corn, characterized by a waxy endosperm, gave an increased kernel weight of 16 per cent for hybrid over pure kernels when pollinated with a mixture of pollen from Chinese and dent corn.

Wolfe [5] reports that crossed kernels of different varieties of corn ranged from 13.45 per cent decrease to 16.04 per cent increase when compared with the pure kernels.

432. Detasseling Corn for Seed Production. Detasseling consists of pulling or otherwise removing the tassel from the corn plant before it has shed its pollen. This has been advised at times in the past in order to insure cross-pollination. In 1905 one of the corn belt experiment stations reported: [6] "From the data we have secured on the subject, we now strongly recommend that every alternate row of corn in the breeding plots be completely detasseled before the pollen matures, and that all of the seed corn be selected from the detasseled rows. This insures cross-pollination and markedly increases the yield of the crop."

In 1910, Calvin, at the Georgia station,[7] reported a yield of 68.04

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[2] Kiesselbach, T. A.—"The Immediate Effect of Gametic Relationships of Parental Type upon the Kernel Weight of Corn." *Nebr. Agr. Expt. Sta. Res. Bul. 33*, p. 5. 1925.

[3] Smith, L. H.—"Plot Arrangements for Variety Experiments with Corn." *Jour. Amer. Soc. Agron.* Vol. 1, p. 84, 1909.

[4] Collins, G. N.—"A New Type of Indian Corn from China." *U. S. Dept. Agr. Bureau Plant Indus. Bul. 161.* 1909.

[5] Wolfe, T. K.—"Further Evidence That the Immediate Effect of Crossing Arises from the Size of Seed Produced." *Jour. Amer. Soc. Agron.* Vol. 7, pp. 265-272. 1915.

[6] Hopkins, C. G., *et al.*—"Directions for the Breeding of Corn, Including Methods for the Prevention of Inbreeding." *Ill. Agr. Expt. Sta. Bul. 100.* 1905.

[7] Calvin, M. Z.—"Corn Production." *Ga. Agr. Expt. Sta. Bul. 93*, p. 151. 1910.

bushels for plots grown from detasseled plots the year previous and 67.25 bushels for plots grown from seed which had not been detasseled.

Kiesselbach obtained a yield of 43.6 bushels per acre on detasseled rows as compared to 42.9 bushels for rows not detasseled. As an 8-year average, seed from the detasseled plants produced 48.6 bushels per acre, while seed from plants not detasseled produced 48.3 bushels.

433. Effect of Detasseling Poor Stalks in the Seed Plot. Kiesselbach[8] also determined the effect of detasseling the better stalks, and leaving the others to be pollinated by the poor stalks, and vice versa. The original Hogue's Yellow Dent seed corn used yielded 51.9 bushels as an 11-year average and 52.8 bushels as a 7-year average. Seed secured where the better stalks were detasseled, so that all the pollen of necessity came from the poorer stalks, produced 48.7 bushels as an 11-year average and 49.4 as a 7-year average; but when the poor stalks were detasseled, the yield was 49.6 and 50.7 bushels, respectively.

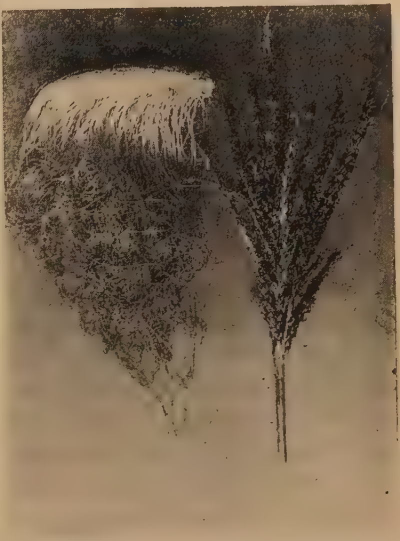

FIG. 89.—In the corn plant the male flowers are borne on the tassel and the female flowers on the ear immediately below. The pollen is spread by the wind. *How much self fertilization occurs in the ordinary field of corn? What is the effect of this on vigor and yield?*

434. The Amount of Normal Self-Fertilization in Corn. It has been shown that the immediate effect of self-pollination is a decrease in yield the following year of approximately 50 per cent. The advisability of detasseling plants from which seed ears are to be saved would seem to depend to a considerable extent upon the amount of self-fertilization which normally occurs in the field.

Hayes[9] reports that the amount of normal self-fertilization under field conditions, as determined by a somewhat limited number of tests, proved to be less than 5 per cent.

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[8] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20.* 1922.

[9] Hayes, H. K.—"Normal Self-fertilization in Corn." *Jour. Amer. Soc. Agron.* Vol. 10, No. 3, p. 126. 1918.

Kiesselbach[10] planted isolated hills of white corn in a field of yellow corn, using varieties which had identical flowering periods. The per cent of self-fertilization was determined by the color of the endosperm of the kernels from the white corn. Any kernels which were doubtful were planted the following year and selfed. It was found that only 0.7 of one per cent of the kernels were self-fertilized.

Waller[11] found an average of 5.13 per cent of self-fertilization, but states that this figure may not represent the per cent of self-fertilization taking place under all field conditions since humidity and wind are factors which determine the zone of infection between hills.

TERMS USED IN CORN BREEDING

435. Some Terms Defined. A few of the more important terms used in corn breeding, with their meaning, are as follows:

Pure line. A pure line has been described as the progeny of a single, homozygous, self-fertilized plant. For all practical purposes a strain of corn may be said to be a pure line after it has been self-fertilized for ten or more generations. It is more accurate to use the term inbred or self-fertilized line.

Xenia. The term applied to the visible effect of the pollen on the corn kernel which develops immediately after fertilization.

Homozygous. This is a term indicating that all the germ cells carry the same hereditary properties.

Heterozygous. The term applied to those plants where the germ cells carry different properties. There are varying degrees of heterozygosity. The nearer a plant comes to being a pure line, the lower is its heterozygosity; and the farther it comes from being a pure line, the greater is its heterozygosity. A plant may be homozygous for one particular pair of characters and heterozygous for other characters. Strains of corn which approach a homozygous condition, such as inbred strains, are generally much reduced in vigor. Increasing the heterozygosity by crossing the inbred strains usually increases the vigor and yield.

Linkage. This is a term used to indicate that two or more characters are inherited together. Some characters of corn affecting different parts of the plant are found to be inherited together, and a selection for one of these two characters would increase the amount of the other. This linkage complicates corn breeding. Desirable characters may be linked with undesirable characters and are thus inherited together. The genes for these characters are carried on the chromosomes. (See 75.) In corn there are 10 pairs of chromosomes. Several characters may be carried by a single chromosome and are, therefore, tied together or linked.

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[10] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20*, 1922.

[11] Waller, A. E.—"A Method for Determining the Per Cent of Self-pollination in Maize." *Jour. Amer. Soc. Agron.* Vol. 9, No. 1, p. 36. 1917.

Gene. The term used to designate the element in the chromosome which determines what the character is going to be; for example, whether the color of the pericarp is to be red or colorless or the endosperm to be yellow or white, etc.

METHODS OF IMPROVING CORN

The corn of a locality or state has been improved in some cases by the introduction of new and better adapted varieties.

436. Improved Varieties and Mass Selection. In the past a comparison of different varieties of corn for adaptation and yield was included in the work of most of the experiment stations. Such comparisons gave some information regarding varieties suitable for a locality. However, seed of the same variety of corn from different growers was found in a good many cases to have as great differences in yield as distinctly different varieties. Corn variety testing, and corn yield tests generally, do not test varieties as such, but particular strains of these varieties as they have been developed by the individual breeder. Some strains which are decidedly superior to the average have been developed. Some varieties and strains of corn have been isolated or improved by careful seed selection, giving attention to such characters as the vigor of the stalk, suitable maturity, freedom from disease, and productivity. On the other hand, too rigid selection for particular types of ears has apparently resulted in some cases in reduced vigor and yield. Continuous selection within a variety tends to isolate a strain. Much of the work that has been done in corn breeding has been in isolating strains, which were either high yielding or possessed desirable characters that could later be combined in building up strains possessing superior qualities.

The comparison of varieties and mass selection of seed as practiced by the best corn growers are important and definite methods of improving corn.

437. Ear-to-Row Breeding. Ear-to-row breeding as a means of increasing the yield was described by Hopkins of the Illinois Experiment Station in 1897. The method was widely adopted and advocated. Many changes and improvements have been made since its first introduction, notably the ear-row-remnant method, first advocated by Williams at the Ohio station in 1905 and which was generally adopted by experiment stations throughout the country. The ear-row-remnant method consists essentially in comparing individual ears for yield in the field by making replicated plantings with a portion of each ear planted in individual rows. The remnant seed of the better-producing ears is used for planting a seed plot the following year, from which future selection may again be made.

438. Results from Ear-to-Row Breeding. Nebraska. In 1909, Montgomery [12] reported that four years' continuous selection by the ear-to-row method increased the yield 7 bushels per acre.

In 1922, Kiesselbach [13] reporting on the later generations of this same corn stated that the eighth to the twelfth year of the selection produced no increase over the original stock.

Kiesselbach also reports ear-to-row breeding work with Nebraska White Prize corn with results as shown in Table *438a.*

438a. Ear-to-row breeding work with Nebraska White Prize; yields in bushels of grain per acre. Nebraska.

	7-Yr. Av. Yield	5-Yr. Av. Yield
Original Nebraska White Prize	54.4	63.7
Continuous ear-to-row breeding	53.8	63.2
Composite of 8 best strains	52.1	60.7
Intercrossing strains	...	64.8

Similar results were obtained with Hogue's Yellow Dent, as will be noted from Table *438b.*

438b. Ear-to-row breeding work with Hogue's Yellow Dent; yields in bushels of grain per acre. Nebraska.

	7-Yr. Av. Yield	No. of Years Each Ranked		
		1st	2nd	Last
Original Hogue's Yellow Dent	53.6	0	3	..
Continuous ear-to-row selection since 1903	53.3	2	0	..
Increase from single high yielding strain selected in 1906	47.7	0	0	7
Increase from a composite of 4 strains selected in 1906	55.0	3	2	..
Intercrossing of 4 strains in 1906	54.5	2	2	..

439. Results from the Ear-to-Row Method. Illinois. Smith and Brunson [14] report the results obtained from ear-to-row breeding. A well-adapted local strain, which in its immediate history had not been subjected to careful selection, was used. A portion of each of the

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[12] Montgomery, E. G.—"Experiments with Corn." *Nebr. Agr. Expt. Sta. Bul. 112.* 1909.

[13] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20.* 1922.

[14] Smith, Louie H., and Brunson, A. M.—"An Experiment in Selecting Corn for Yield by the Method of the Ear-to-Row Breeding Plot." *Ill. Agr. Expt. Sta. Bul. 271.* 1925.

990 ears grown the first year was mixed and grown separately to represent the original strain of corn for purposes of comparison each year. This was called the "non-pedigreed strain." Another strain of corn called the "special high yield strain" was started after the experiment had been going for 5 years. Relative yields for 5-year periods and the significance of the differences determined are reported in Table *439a*.

439a. Comparative yield of different strains of corn isolated by the ear-to-row method. Illinois.

Strains Compared	Period	Difference in Bushels per Acre	Odds That Difference Is Significant
High yield over low yield.........	First 5 years Second 5 years	5.80 15.17	9999:1 9999:1
High yield over non-pedigree.....	First 5 years Second 5 years	1.27 1.42	3.1:1 3.4:1
Non-pedigree over low yield.......	First 5 years Second 5 years	4.53 13.75	34.6:1 9999:1
High yield over special high yield.	1918–1922	.09	1.1:1
High yield over Reid Yellow Dent.	First 5 years Second 5 years	4.58 6.85	216:1 37:1
Non-pedigree over Reid Dent.....	First 5 years Second 5 years	3.31 5.43	18:1 18:1

These investigators conclude that continuous selection by means of the ear-to-row breeding plot cannot be recommended as a means of increasing the yield of a well-adapted variety of corn. They state also that by continuous mass selection the yield of a well-adapted variety of corn can be maintained and perhaps somewhat increased.

440. Methods Compared at the Minnesota Station. Hayes and Alexander[15] compared various methods of selecting seed for planting. (1) In the first method the better-appearing ears were reserved for seed as the corn was shocked. (2) In the second the selection was made in the field from perfect stand hills and vigorous stalks. Well matured ears were chosen but no close selection of ear type was made. (3) The third method of selection was the same as the second except that the selected stalks were cut and shocked and then husked later in the fall. (4) In the fourth method ears were selected from perfect stand hills in the field, only those ears of high scoring type according to the corn score card being saved for seed. (5) In the fifth, called the

[15] Hayes, H. K., and Alexander, Lee—"Methods of Corn Breeding." *Minn. Agr. Expt. Sta. Bul. 210.* 1924.

"Montgomery" method, the ear-to-row test was used the first year and seed from the remnants of the 25 better yielding mother ears, as determined by the ear-to-row test, were mixed for planting the following year. (6) The sixth was the Williams method, which isolated high yielding ears by the ear-to-row method, followed by crossing the remnants of the 3 high yielding ears the following year, and planting this F_1 seed the third year. In this test the crossing plots or multiplying plots were used each year. (7) The seventh was the same as the sixth except that the seed used was obtained from plantings of the F_1 seed in the increase plot. The results of these methods of breeding as a 4-year average and the relative rank for each year is reported in Table *440a.*

440a. Yields of corn obtained from various methods of breeding compared with mass selection. Minnesota.

Method	4-Yr. Av. Yld.	Rank			
		1920	1921	1922	1923
1. Selection of good ears at husking time	54.5	1	3	4	5
2. Perfect stand hills, seed stored immediately	54.4	4	3	2	2
3. Perfect stand hills, seed cured in shock	54.3	3	5	4	2
4. Perfect stand hills, seed scored by score card	53.2	6	5	7	6
5. Montgomery ear-to-row then mixed high yielding remnants	55.2	2	1	1	4
6. Williams' method F_1 of 3 high yielding ears	55.5	5	2	3	1
7. Williams' method, increase 1 year of 6 (3 yrs.)	55.8	Not in	7	6	7

441. Other Tests with the Ear-to-Row Method. Hume[16] reports an increase of 2.4 bushels as a 7-year average for continuous ear-to-row selection. However, the last 3 years showed a decrease of 0.2 bushel per acre.

Ear-to-row work was started at the Pennsylvania station in 1908. Clowe[17] reports the yield of Clarage corn bred by the ear-to-row method to be 56.6 bushels in comparison with a yield of 56.4 from seed of the general field.

442. Hybrid Vigor. When two varieties or strains of corn are crossed, that is, the pollen of one strain allowed to fall on the silks of the other, the progeny is likely to be more vigorous than the average of the parents. This vigor is referred to as "hybrid vigor." It is believed that closely related selections or strains give less increase as a rule than do those more widely separated in breeding. Increased vigor due to hybridization is likely to result in the first generation only. If ears produced from the first generation planting are used for seed, the hybrids break up again with new combinations, loss of vigor, and yields which may average lower than the original parents.

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[16] Hume, A. N.—"Corn Families of South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 186.* 1919.

[17] Clowe, C. F.—"Experiments with Corn." *Pa. Agr. Expt. Sta. Bul. 139.* 1916.

Jones and Mangelsdorf[18] report a cross between two inbred strains which averaged 101 bushels per acre, but seed of the second generation of this cross gave an average of 69 bushels, a decrease of more than 30 per cent.

443. Hybrids from Varieties. Many experiment stations have crossed different varieties of corn and compared the yield of the hybrids with those of the parents.

Richey[19] has summarized the results of 244 comparisons between first generation crosses and the parent varieties.

443a. First generation hybrids compared with parents for yield. Summary.

Reference	Total No. of Hybrids	Yielding Less Than Poorer Parent	As Compared with Average of Parents		Better Than Better Parent
			Above	Below	
B. P. I. Bul. 218	96	4	83	13	51
Conn. Ann. Rpt. 1913	36	1	29	7	19
Conn. Bul. 168	2	0	2	0	..
Minn. Bul. 183	33	2	28	5	22
Va. Tech. Bul. 18	4	0	3	1	1
Conn. Ann. Rpt. 1916	50	2	44	6	33
Pa. Bul. 139	10	3	3	7	3
Ohio Bul. 282	13	2	9	4	7
Totals	244	14	201	43	136
Percentage	100	5.7	82.4	17.6	55.7

444. Hybrids from Selfed Lines. As a method of breeding corn selection within self-fertilized lines offers promise to obtain increased yields. In this method numerous plants are self-pollinated and the seed of the resulting ears planted, an ear to the row. Individual ears in each of these rows are again self-pollinated and the selfed ears from the better plants in the better rows selected for continuing the breeding program. Many of the selfs are so poor that they are worthless, and no selfed line has thus far been found which is equal to the

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[18] Jones, D. F., and Mangelsdorf, E. C.—"Crossed Corn." *Conn.* [*New Haven*] *Agr. Expt. Sta. Bul. 273*, p. 168. 1926.

[19] Richey, F. D.—"Experimental Basis for the Present Status of Corn Breeding." *Jour. Amer. Soc. Agron.* Vol. 14, Nos. 1 and 2, p. 6. 1922.

444a. The effect of narrow and broad fertilization of Nebraska White Prize corn on its plant characteristics. Nebraska.

DEGREE OF INBREEDING	STALK HEIGHT (IN.)	EAR HEIGHT (IN.)	EARS PER 100 PLANTS	SUCKERS PER 100 PLANTS	SHRINKAGE OF EAR CORN (%)	SHELLING PER CENT	AVERAGE (BU.)
1. Inbreeding[a]	87	40	80	7	14.0	76.6	22.3
2. Close breeding[b]	94	43	91	11	14.0	80.5	42.7
3a. Narrow breeding[c]	97	50	97	12	13.0	80.2	48.9
3b. Narrow breeding[d]	97	48	93	16	13.8	81.6	44.8
Av. 3a and 3b[e]	97	49	95	14	13.4	80.9	46.8
4. Broad breeding[f]	98	50	99	16	13.0	81.1	51.3
5. Natural crossing[g]	101	51	99	16	10.8	82.2	64.8
6. Natural crossing[h]	100	50	104	20	8.0	83.1	64.0
7. Original Nebr. White Prize[i]	101	50	104	18	10.0	82.9	63.7

[a] Single ear self-fertilized. Inbred from 1912 yields for period 1915 to 1921.
[b] Single ear fertilized with pollen from single sister plant.
[c] Single ear fertilized with composite pollen from sister plants.
[d] Composite ears fertilized with pollen from single sister plant.
[e] Average of classes 3a and 3b.
[f] Composite ears fertilized with composite pollen from sister plants.
[g] Between ear-to-row strains.
[h] Between varieties—Nebraska White Prize and Hogue's.
[i] Wind pollinated.

parent in vigor or yield. After corn has been self-fertilized for several years, it becomes very much reduced in vigor. Defects appear which have been hidden due to their recessive nature. Kiesselbach[20] reports the effect of self-fertilization on Nebraska White Prize corn and the way it affects certain characteristics in Table *444a*.

After the selfed lines have been purified for several years, the better lines may be used in crosses. Two selfed lines may be used to make a single cross, or several may be used in making a composite cross, using only first generation seed in all cases. A third method of using selfed lines of corn is to intercross several of these strains, maintaining the mixture of crosses by mass selection in the field.

Richey[21] states that it seems improbable that a strain of corn made by combining many crosses can be obtained, which will give as good a yield as the best of the component parts in the F_1 generation. The productiveness of such a mixture in the later generations, after segregation and recombination of genetic factors has come about, is even more problematic. Nevertheless, the practical advantages of seed production and distribution may make this method worthwhile.

445. Results Obtained from Hybridizing Selfed Lines. Shull,[22] in 1910, obtained 68.07 bushels per acre as an average of 7 pure line hybrids as against 61.52 bushels from 10 crossbred strains.

Noll[23] reports that of 20 pure line crosses compared in 1914 at the Pennsylvania Station, 13 produced more and 7 less than the average of the original parental varieties. The 3 best crosses produced increases of 11.5, 6.4, and 5.9 bushels per acre. The 4 best crosses in 1915 averaged 7.7 bushels per acre more than the non-inbred parent.

Jones[24] reports the yields of 25 crosses of inbred strains of Leaming. Fourteen of the crosses produced more and 11 produced less than the original variety. Eight of the crosses having one particular strain as the pistillate parent were all high yielding, while 6 of the 11 poor crosses had a particular strain of corn as the pistillate parent. This indicates the consistent value of individual lines.

Jones[25] reports his double cross Burr-Leaming corn as yielding 74 bushels of shelled grain per acre as a 9-year average in comparison with 63 bushels from the next highest yielding variety grown during the same period. This is a gain of 17 per cent. Burr-Leaming also has the distinct advantage of standing erect in the field throughout the season where other varieties have gone down badly. Another characteristic noted in this corn is the tendency to hold its leaves green until the grain is ripe, indicating resistance to disease, and resulting in a better quality of ensilage.

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[20] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20*, p. 73. 1922.

[21] Richey, F. D.—"Convergent Improvement of Selfed Lines of Corn." *Amer. Nat.* Vol. 61, p. 431. Sept. and Oct., 1927.

[22] Shull, George Harrison—"The Genotypes of Maize." *Amer. Nat.* Vol. 45, p. 248. 1911.

[23] Noll, C. F.—"Experiments with Corn." *Pa. Agr. Expt. Sta. Bul. 139.* 1916.

[24] Jones, D. F.—"The Effect of Inbreeding and Cross Breeding." *Conn. [New Haven] Agr. Expt. Sta. Bul. 207.* 1918.

[25] Jones, D. F.—"Double Cross Burr-Leaming Seed Corn." *Conn. Agr. Col. Ext. Bul. 108*, p. 5. 1927.

In 1923, the average yield of 8 hybrids of selfed strains at the Iowa station was 11.8 per cent greater than the average of the 8 highest yielding open-pollinated strains with which they were compared. In 1924, the yield of 4 hybrids was 28 per cent more than that of 34 open-pollinated strains with which they were compared. In 1925, 10 hybrids produced 7.5 per cent more than the average of all entries in the field in which they were grown.

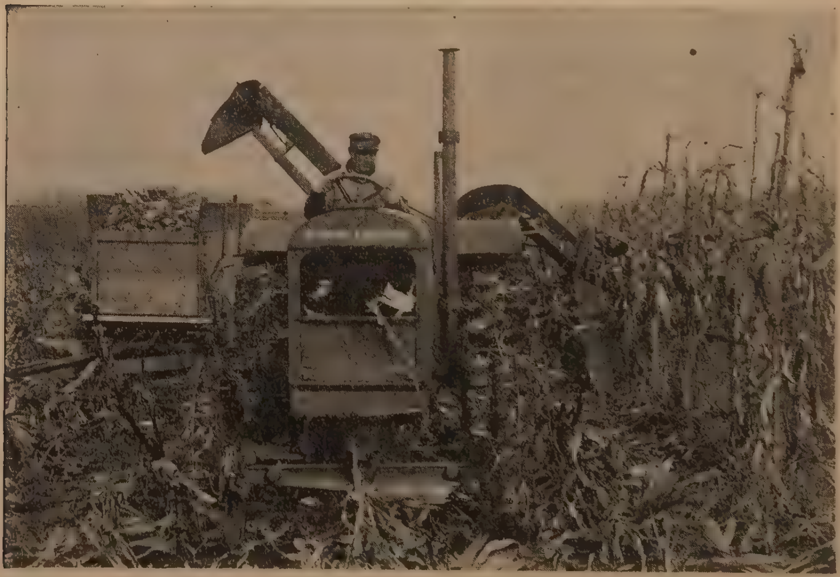

FIG. 90.—With the increased use of corn-picking machinery, there is a persistent demand for strong stalked corn which will stand straight until the end of the season. *What method of corn breeding makes possible stronger stalked strains than have been available heretofore?*

In 1926, 133 entries of hybrids from selfed lines and 367 entries of open-pollinated strains were made in the Iowa State Corn Yield Test.[26] The average yield of the open-pollinated varieties for the 12 different districts into which the state is divided was 59.42 bushels per acre as compared with 67.6 bushels for the hybrids, a gain of 13.77 per cent.

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[26] Robinson, Joe L., and Bryan, A. A.—"Hybrid Corn Breeding." *Iowa Yearbook Agr. 1926*, pp. 42-43.

In 1929, of 516 entries 230 were hybrids. Averaging the two classes by districts, the gain of the hybrids was from 3.4 to 24.1 per cent.

Hayes[27] reports one double cross between pure lines which outyielded commercial varieties by 30 per cent; 7 crosses that led by 13 per cent, and 3 that yielded less than the commercial varieties.

Richey[28] compared 70 F_1 crosses of lines of corn which had been self-fertilized for 6 generations with the yield of the parent variety. The average yield of 3 of these crosses was 30 per cent more than that of the parent variety.

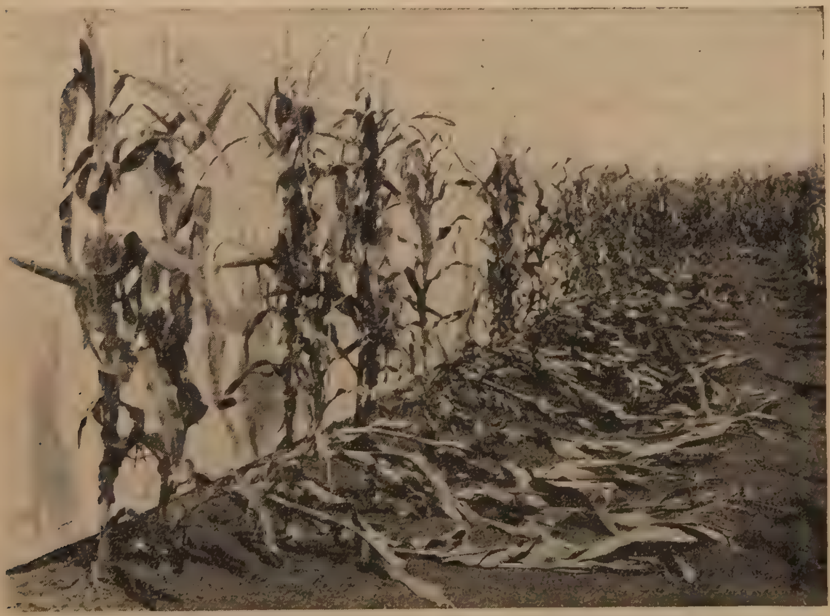

Fig. 91.—The product of a cross between a strong stalked inbred strain and a weak stalked inbred. (Iowa Station.)

Richey states that the principal rôle of self-fertilization is to isolate definite lines, differing from each other, among which selection may be practiced. For practical reasons it is desirable to have inbred lines productive in themselves, but the evidence indicates that there is little relation between the productiveness of the self-fertilized lines and that of their crosses, and that the final value of the line for crossing must be determined by comparison of the productiveness of their crosses.

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[27] Hayes, H. K.—"Present-Day Problems of Corn Breeding." *Jour. Amer. Soc. Agron.* Vol. 18, pp. 344-363. 1926.

[28] Richey, F. D., and Mayer, L. F.—"The Productiveness of Successive Generations of Self-fertilized Lines of Corn and of Crosses between Them." *U. S. Dept. Agr. Dept. Bul. 1354*, p. 17. 1925.

STUDY QUESTIONS ON CHAPTER XV

1. If a tall strain of corn is crossed with a short strain, the tall being dominant, what will the progeny be like the first year? The second year, if self-fertilized? The third year?
2. Why does pollen from yellow or from blue ears produce yellow or blue kernels at once on a white corn, while that from a red corn does not produce a red kernel?
3. Explain why sweet corn which has crossed with field corn can be easily separated, while it is very difficult to separate field corn which has crossed with sweet corn.
4. When several varieties of corn are grown in plats side by side in a yield comparison, is the yield of the more productive strains influenced by the pollen from the less productive kinds? Explain?
5. Would you advise a farmer growing a certain variety to detassel his corn in order to be certain that self-fertilization will not occur? Why?
6. A farmer writes, "Outline the use of the ear-to-row method of corn breeding. Would you advise me to use this method? I have a very uniform corn, but it does not yield well."
7. "I have strains of corn which I wish to cross. What is the best way to do this and do you advocate this method of breeding?" What advice would you give in answer to the foregoing question?
8. What is "pure line" corn and how can one use it to improve yields?
9. Outline a method of seed selection or breeding which the average farmer might use to improve or maintain a strain of corn.

APPLICATION ASSIGNMENTS ON CHAPTER XV

1. You have a field of white corn grown near yellow corn. How and why can you be certain that seed picked from the white field is pure? Suppose you were growing yellow corn. How could you be certain it was pure?
2. You are not satisfied with the yield you are securing from your corn. Outline different ways in which you might determine its productivity in comparison with other strains available. Which plan will you use? Why?
3. You find that other strains of corn are more productive than the corn you are growing. You wish to continue with your present variety and plan to undertake a breeding program which will increase its productivity. Tell just how you will go about doing this.
4. You and your neighbor each purchased seed corn 10 years ago from the same source. You have continuously practiced ear-to-row breeding and careful seed selection, while he has selected his seed from the crib each year. In a yield test his corn proved more productive. Explain.

CHAPTER XVI

CORN PRODUCTION

The profit in corn production is represented by the difference between the value of the crop and the cost of production. The cost of growing the crop is largely determined by the practices and principles considered in this chapter, as is also the acre production.

446. The Seedbed. The principles involved in the preparation of a seedbed for corn have been discussed. (282 and 284.) In most cases both the disk and harrow are used in fitting the seed bed, whether the land has been plowed in the fall or in the spring. Listing is the common method of seedbed preparation in the dry-land areas of the Great Plains and in certain sections of the South, though on the heavier lands in the South bedding is more general. Thorough disking of the land without plowing is mentioned as being a minor method in several states.

METHODS OF PLANTING CORN

447. Methods of Planting. Three common methods are in use in the planting of corn. Over the greater part of the corn belt the crop is surface planted, the land first being plowed, disked, and harrowed, till fine and smooth. With the second method, used to a limited extent, the crop is also planted on flat prepared ground but in shallow furrows. Furrow openers are used on the shoe of the planter, opening up the surface of the soil so that the corn is planted in shallow furrows. The third method consists in planting in the furrow of listed ground. The land may be listed and planted in one operation without first plowing, though in some cases the land is both plowed and listed. Bedding in the South is sometimes done with a lister, in which case the ridges are dragged down somewhat, and in wet soils planting is done on top of the ridge. Occasionally, in Washington and Oregon, corn has been seeded with a grain drill.

448. Hill Planting *vs.* Drilling. Corn is either planted in drills, in which case it can be cultivated one way only, or checked in hills so that it may be cultivated both ways across the field. There is a general impression that drilled corn will yield more than checked corn. A number of stations have compared drilled and checked corn with the yields reported in bushels of grain per acre in Table *448a*.

448a. Comparisons of drilled and checked corn; yield in bushels per acre. Summary.

	DRILLED			CHECKED		
		Grain Bu. per Acre	Stover Lbs. per Acre		Grain Bu. per Acre	Stover Lbs. per Acre
Md.[a]	1 ker. every 22″	50.7	2618	2 ker. every 3′9″	47.6	2394
Ohio[b]	1 ker. " 12″	46.88	2827	3 ker. " 36″	42.33	2168
Ohio[b]	2 ker. " 24″	46.28	2417	4 ker. " 48″	42.85	2180
Minn.[c]	1 ker. " 18″	50.57	....	2 ker. " 3′8″	42.9	....
				3 ker. " 3′8″	55.15	....
Ark.[d]	1 ker. " 22″	42.1	....	2 ker. " 44″	42.7	....
Ark.[d]	1 ker. " 14⅔″	47.4	....	3 ker. " 44″	40.3	....
Ark.[d]	1 ker. " 11″	46.1	....	4 ker. " 44″	46.3	....

[a] Patterson, H. J. "Variety and Culture Experiments with Wheat, Corn, and Potatoes." *Md. Agr. Expt. Sta. Bul. 62.* 1899.

[b] Williams, C. G., and Welton, F. A. "Corn Experiments." *Ohio Agr. Expt. Sta. Bul. 282.* 1915.

[c] Bull, C. P. "The Relation of Number of Stalks per Hill to Yield." *Minn. Agr. Expt. Sta. Bul. 149.* 1915.

[d] Osborn, L. W. *Ark. Agr. Expt. Sta. Bul. 200.* 1925. (Nine-year average.)

449. The Rate of Planting. Corn planted 3 feet 6 inches each way gives 3556 hills per acre. With a perfect stand, each stalk producing a 10-ounce ear, 1 plant per hill will yield approximately 32

FIG. 92.—The greater part of the corn crop is hill planted. *Under what conditions, if ever, is drilling advisable? Is it possible under certain conditions to get greater yields by drilling? What do the data available indicate?*

bushels per acre; 2 plants per hill, 64 bushels; 3 plants, 96 bushels; 4 plants, 128 bushels. The rate of planting may be varied by changing the distance between rows or between hills and by changing the number of kernels planted per hill.

450. Width of Rows and Hills. Hume, Center, and Hegnauer[1] report the effect of varying the distance between the hills and the number of kernels per hill.

450a. Number of kernels per hill and the distance between hills and rows; yields reported in bushels per acre, are average for six years. Illinois.

LOCATION	KERNELS PER HILL	DISTANCE BETWEEN ROWS AND HILLS (INCHES)						
		44x44	44x39.6	44x36	44x33	36x36	33x36	33x33
Northern Illinois.....	2	44.1	47.1	48.7	50.9	54.2	54.3	52.0
Northern Illinois.....	3	54.1	55.7	56.7	57.7	58.9	59.9	61.0
Central Illinois.....	2	47.7	50.0	51.9	52.8	54.5	55.0	54.0
Central Illinois.....	3	51.6	51.9	52.3	51.4	49.1	49.1	46.8

Mooers[2] reports a 5-year comparison with different widths between the hills when planting 1, 2, and 3 kernels per hill so that there would be the same number of plants per acre. The one-kernel hills produced 49.6 bushels of grain and 1.79 tons of stover; 2 kernels per hill, 49.9 bushels of grain and 1.76 tons of stover; 3 kernels per hill, 47.4 bushels of grain and 1.66 tons of stover.

Mooers compared 3.5-foot rows and 7-foot rows with the same number of plants per acre. In 1914, the 7-foot rows yielded 75 bushels of grain and 3.42 tons of stover, while the 3.5-foot rows yielded 88.4 bushels of grain and 4.81 tons of stover. Similar differences were obtained in 1915. Mooers[3] also tested the rate of planting on poor soil at Jackson and on rich soil at Knoxville. Climatic conditions, the soil, and the growth habits of the variety are all factors which influence the results.

Conner[4] reports the results of extensive tests at College Station and at six substations in Texas, comparing corn in 3-foot rows with

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[1] Hume, Albert N., *et al.*—"Distance between Hills of Corn in the Illinois Corn Belt." *Ill. Agr. Expt. Sta. Bul. 126.* 1908.

[2] Mooers, C. A.—"Planting Rates and Spacing of Corn." *Tenn. Agr. Expt. Sta. Bul. 124.* 1921.

[3] Mooers, C. A.—"Planting Rates and Spacing of Corn under Southern Conditions." *Jour. Amer. Soc. Agron.* Vol. 12, No. 1, p. 16. Jan., 1920.

[4] Conner, A. B.—"Spacing of Rows in Corn and Its Effect upon Grain Yield." *Tex. Agr. Expt. Sta. Bul. 230.* 1918.

450b. Fertility of soil as influencing best rate of planting. Tennessee.

	THOUSANDS OF PLANTS PER ACRE											
	1	2	3	4	5	6	7	8	9	10	11	12
Knoxville (rich)	15.2	25.7	29.6	40.0	46.5	50.5	51.7	50.8	46.7	41.2	43.5	37.8
Jackson (poor)	9.8	14.6	17.8	13.2	14.2	14.0	9.9	...	...	...	...	...

6-foot rows. Three-foot rows averaged, for all stations, 21.98 bushels; 6-foot rows, 20.1 bushels.

Osborn[5] spaced plants in standard width rows, 11, 14⅔, 18, 24, 30, 36, 40, and 44 inches apart and obtained yields of 34.7, 38.1, 38.8, 35.5, 29.0, 27.4, 23.0, and 26.0 bushels per acre, respectively for an average of 2 varieties each year for a 2-year period. Number of plants per acre for these rates of planting as a 4-year average was 12,960, 9720, 7920, 5940, 4940, 4116, 3605, and 3240, respectively.

Zook and Burr[6] report that at the Nebraska Station corn planted 24 inches apart and 48 inches apart in 3-foot 6-inch rows yielded 21.3 bushels and 19.4 bushels, respectively, while with corn planted 12 inches and 24 inches apart in 7-foot rows the yield was 20 bushels and 16.2 bushels, respectively, as a 6-year average.

The Ohio Station[7] reports that in 1924 planting sweet corn in 30-inch rows with 2 plants every 15 inches produced 44 per cent more and in 1925 19.5 per cent more than 3 plants every 34 inches in rows 36 inches apart.

FIG. 93.—Three stalks per hill is regarded as the ideal rate of planting over a wide territory. *Under what conditions is thicker planting to be recommended? When is thinner planting advisable?*

451. Kernels per Hill. The yields obtained at a number of corn belt stations from different rates of planting are summarized in Table *451a*.

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[5] Osborn, L. W.—"Experiments with Varying Stands and Distribution of Corn." *Ark. Expt. Sta. Bul. 200.* 1925.

[6] Zook, L. L., and Burr, W. W.—"Sixteen Years' Grain Production at the North Platte Substation." *Nebr. Agr. Expt. Sta. Bul. 193.* 1923.

[7] Williams, C. G.—"Forty-fourth Annual Report of the Ohio Agricultural Experiment Station for the Year Ended June 30, 1925." *Ohio Agr. Expt. Sta. Bul. 392.* 1926.

451a. Rate of planting as influencing yield. Summary.

Duration	No. of Kernels per Hill					
	1	2	3	4	5	6
Mo.[a] 3 yrs.	....	43.7	41.4	....	....	....
Ill.[b] 1 yr.	....	40.8	46.0	49.0	48.1	....
Nebr.[c] 6 yrs.	48.3	67.7	75.5	76.7	76.3	....
Ky.[d] 2 yrs.	....	51.6	58.1	60.4	....	....
S. Dak.[e] 3 yrs.	18.6	26.1	28.2	20.1	....	....
Minn.[f] 5 yrs.	....	42.9	55.1	55.9	53.9	44.6
Ohio[g] 21 yrs.	31.91	51.26	62.92	66.64	65.79	....
N. Dak.[h] 2 yrs.	15.4	26.1	31.0	31.9	32.1	34.6
Ohio[i] 10 yrs.	31.70	50.83	60.77	64.90	62.98	....

[a] *Mo. Agr. Expt. Sta. Bul. 185.* 1921.
[b] *Ill. Agr. Expt. Sta. Bul. 37.* 1895.
[c] *Nebr. Agr. Expt. Sta. Bul. 112.* 1909.
[d] *Ky. Agr. Expt. Sta. Bul. 163.* 1912.
[e] *S. Dak. Agr. Expt. Sta. Bul. 181.* 1918.
[f] *Minn. Agr. Expt. Sta. Bul. 149.* 1915.
[g] *Wallace's Farmer.* Vol. 50, No. 18, p. 641. May 1, 1925.
[h] *N. Dak. Agr. Expt. Sta. Bul. 51.* 1902.
[i] *Ohio Agr. Expt. Sta. Bul. 282.* 1915.

In Iowa, Robinson and Bryan[8] report yield comparisons made in the north, north central, south central, and southern parts of the state, planting, 2, 3, 4, and 5 kernels per hill. The plants per hill at harvest

451b. Rate of planting, plants at harvest and acre yield in bushels; five-year average. Iowa.

Section of State	No. Kernels per Hill	Plants per Hill at Harvest	Yield Bushels
Northern	2	1.7	47.38
	3	2.47	58.35
	4	3.06	62.35
	5	3.68	65.81
North Central	2	1.71	48.61
	3	2.43	58.64
	4	3.09	60.75
	5	3.74	61.41
South Central	2	1.65	53.52
	3	2.36	64.19
	4	3.09	67.20
	5	3.76	66.63
Southern	2	1.69	51.50
	3	2.29	62.63
	4	2.90	61.11
	5	3.56	61.96

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[8] Robinson, J. L., and Bryan, A. A.—*Results of 1926 Corn Yield Test.* Iowa Corn and Small Grain Growers' Association, Ames, Iowa.

time and the yield in bushels per acre of dry shelled corn is reported in Table *451b*.

The yields are average for a 5-year period with 3 fields in each section each year. The per cent of plants at harvest to kernels planted was as follows: 2 kernels, 84 per cent; 3 kernels, 80 per cent; 4 kernels, 76 per cent, and 5 kernels, 74 per cent.

In Ohio[9] with corn in hills 3 feet 6 inches apart each way, all plots were planted thick and later thinned to the desired stand. The effect of the rate of planting on the yield in good and in poor crop years and the average yield for a 21-year period is shown in Table *451c*. (483)

451c. Rate of planting in favorable and unfavorable years; yields in bushels per acre of shelled corn. Ohio.

Stalks per Hill	1	2	3	4	5
Av. 4 yrs. of lowest yields, 1910-1907-1923-1912	25.4	40.3	45.8	44.2	41.2
Av. 4 yrs. of highest yields, 1905-1909-1917-1921	37.7	63.4	79.2	85.7	89.9
21-year average 1904 to 1924	31.9	51.3	62.9	66.6	65.8

Other observations from the Ohio station on the character of the corn crop when planted at different rates are shown in Table *451d*.

451d. Effect of rate of planting on growth characters. Ohio.

Plants per Hill	1	2	3	4	5
Plants per acre bearing good ears	3410	5794	7663	8240	7982
Weight per ear in ounces	11.5	11.0	9.7	8.5	8.0
Plants per acre bearing nubbins	580	976	1727	3290	5158
Weight per nubbin in ounces	4.3	4.2	4.2	4.2	4.1
Barren plants per acre	302	762	1615	2937	4867
Two-eared plants per acre	737	422	340	247	232
Av. wt. of ear per stalk in ounces, 21 years	10.4	10.1	8.8	7.4	6.5
Av. wt. of ear per stalk in ounces, best year	10.8	12.5	11.4	10.0	9.0
Av. wt. of ear per stalk in ounces, poorest year	8.6	7.0	5.3	4.2	4.3

It was shown in studies at the Arkansas station[10] that the maturity of the variety and the growing conditions may influence the best rate of planting. The yields per acre for this test are given in Table *451e*.

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[9] Wallace, H. A.—"What Thick Planting Does to Corn." *Wallace's Farmer*. Vol. 50, No. 18, p. 641. May 1, 1925.

[10] Osborn, L. W.—"Experiments with Varying Stands and Distribution of Corn." *Ark. Agr. Expt. Sta. Bul. 200*. 1925.

451e. A summary of rates of planting experiments under favorable and unfavorable conditions, showing average yields for each rate of planting of the different groups of varieties of the cotton belt and of the corn belt. Arkansas.

	No. of Tests	Favorable Conditions Number of Plants per A.					No. of Tests	Unfavorable Conditions Number of Plants per A.				
		3000	4000	6000	9000	12000		3000	4000	6000	9000	12000
Cotton Belt Varieties:												
Late in maturity (135-136 days); prolific..........	8	35.1	44.8	48.1	51.7	51.7	9	22.3	23.6	17.9	13.8	10.3
Medium to medium late in maturity (121-143 days); prolific and medium; prolific	10	36.8	43.5	50.7	49.8	43.5	10	25.6	25.8	19.6	13.2	9.4
Corn Belt Varieties:												
Medium late in maturity (133-146 days)...........	6	31.1	40.9	47.7	44.5	42.1	6	21,1	25.7	19.1	12.8	10.7
Medium and medium early in maturity (120-142 days)	10	29.3	36.3	44.5	46.1	43.5	10	20.9	23.8	21.5	18.9	14.6
Early in maturity (114-135 days)....................	8	25.6	31.8	41.6	47.3	46.6	7	19.0	20.7	21.7	19.6	17.6
Very early in maturity (110-129 days).............	6	15.5	23.2	29.8	33.2	33.8	4	11.8	13.9	18.3	15.5	14.8

Kiesselbach [11] reports the effect of planting Hogue's Yellow Dent at the rate of 1, 3, and 5 kernels per hill. The effect of the rate of planting on various characteristics as an average for a 7-year period is as shown in Table *451f*.

451f. Rate of planting as influencing plant characters. Nebraska.

PLANT CHARACTERISTICS	1 KERNEL	3 KERNELS	5 KERNELS
1. Stalk height (inches)	88	88	88
2. Ear height (inches)	45	44	43
3. Date ripe	9/24	9/23	9/22
4. Lodging (per cent)	11	26	35
5. Two-eared stalks per 100 plants	39	11	8
6. Ears per 100 plants	170	86	63
7. Suckers per 100 plants	101	25	10
8. Shrinkage of ear corn (per cent)	10.5	10.1	10.3
9. Shelling (per cent)	83.2	83.6	82.1
10. Yield in bushels	36.6	44.6	40.3

Montgomery [12] has reported the effect of planting at the rate of 1, 2, 3, 4, and 5 kernels per hill over a 6-year period on various characteristics of the plant. The results are given in Table *451g*.

451g. Effects of rate of planting on different characters. Nebraska.

PLANTS PER HILL	YIELD PER ACRE	AV. WT. OF EACH EAR, OZ.	NO. OF EARS PER 100 PLANTS	NO. OF TILLERS PER 100 PLANTS	NO. OF 2-EARED PLANTS PER 100 PLANTS	PER CENT BARREN STALKS
1	48.3	10.5	161	138	13.3	3.0
2	67.7	10.6	115	60	4.9	4.8
3	75.5	9.4	95	25	2.4	6.9
4	76.7	8.2	82	10	.8	8.3
5	76.3	7.4	77	3	1.1	10.8

452. Tillering of Corn. Tillering is the branching of the plant at or near the crown and is called suckering in corn. It is generally believed to represent an effort on the part of the plant to adjust itself to its environment, making as full use as possible of the plant food and moisture available to it. The intimate relation between rate of planting and tillering will have been observed in the previous division. Sherwin,[13] summarizing some of the views on the causes of suckers, states that the two factors most largely responsible for abundant suckering are a rich soil and abundant moisture. Early planting, shallow planting, a thin stand, good cultivation, and cold nights are also mentioned as influencing the tendency to sucker.

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[11] Kiesselbach, T. A.—"Corn Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 20*, p. 148. 1922.

[12] Montgomery, E. G.—"Experiments with Corn." *Nebr. Agr. Expt. Sta. Bul. 112.* 1909.

[13] Sherwin, M. E.—"Observations on the Status of Corn Growing in California." *Calif. Agr. Expt. Sta. Circ. 70*, p. 15. 1916.

Montgomery[14] tested the effect of removing suckers on the yield of corn,—both grain and stover yields,—with the results shown in Table *452a*.

452a. Effect of removing suckers on the yield of corn. Nebraska.

RATE OF PLANTING	AVERAGE YIELD BUSHELS PER ACRE			
	Tillers Pulled Off		Tillers On	
	Grain	Stover	Grain	Stover
1	31.8	2208	45.9	5061
2	56.4	4200	66.1	5127
3	64.4	4687	69.6	5115
4	71.4	5602	73.2	5801
5	72.6	5987	76.7	6043

Ricks[15] states that pulling the suckers from corn has never given an increase in yield in Mississippi. Similar results are reported from New Jersey[16] and New Hampshire.[17]

Thompson[18] reports that pulling the suckers from Golden Bantam and Stowell's Evergreen sweet corn had resulted in a reduction in yield of both corn and stover, without any apparent gain in earliness, size of ears, or other important advantages.

453. Depth of Planting. Salmon[19] states that corn should be planted sufficiently deep to insure the kernels being placed in moist soil without danger of drying out, usually about 1½ to 3 inches. In wet, heavy soils 1½ inches or possibly less may be sufficient, while in light soils 3 inches or more may be necessary for best results. In western Kansas, deep planting is sometimes desirable in order to prevent the soil around the corn from drying out. Early planting does not need to be so deep as plantings made later in the season. There are certain varieties of corn which can be planted much deeper than others.

Halsted,[20] in a study of the environment as influencing the viability and vigor of corn, planted large and small kernels of flint, flour, and sweet corn at varying depths from 1 to 8 inches. The percentage of viability for each of the several depths was: 94 for 1 inch, 91.5 for 2 inches, 85 for 3 inches, 81.5 for 4 inches, 57.9 for 5 inches, and 28.7 for 8 inches. Large kernels withstood deep planting better than small ones and flint withstood deep planting better than flour corn, while sweet corn was most seriously affected.

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[14] Montgomery, E. G.—"Experiments with Corn." *Nebr. Agr. Expt. Sta. Bul. 112*. 1909.

[15] Ricks, J. R.—"Corn." *Miss. Agr. Expt. Sta. Bul. 170*. 1915.

[16] DeBaun, Roscoe W.—"Sweet Corn Suckering Experiments." *N. J. Agr. Expt. Sta. Ann. Rpt. 28*, pp. 61-63. 1915.

[17] Hepler, J. R.—"Suckering Sweet Corn." Report of the Director of the New Hampshire Agricultural Experiment Station for the year ending June 30, 1921. *N. H. Agr. Expt. Sta. Bul. 203*. 1922.

[18] Thompson, H. C.—"Results of Sweet Corn Suckering Experiments." *N. Y. [Cornell] Agr. Expt. Sta. Bul. 450*. 1926.

[19] Salmon, S. C.—"Corn Production in Kansas." *Kans. Agr. Expt. Sta. Bul. 238*. 1926.

[20] Halsted, Byron D.—"Studies on Heredity and Environment." *N. J. Agr. Expt. Sta. Ann. Rpt. 38*, p. 375. 1917.

Depth of planting comparisons have been made at a number of experiment stations with results as reported in Table *453a.*

453a. Depth of planting corn and yield per acre. Summary.

STATION	NO. YEARS	DEPTH IN INCHES						
		1"	2"	3"	4"	5"	6"	7"
		Bu.	Bu.	Bu.	Bu.	Bu.	Bu.	Bu.
Ill.[a]	5	77.5	71.5	65.1	68.7	61.3	60.0	40.5
Ind.[b]	8	42.8	42.36	42.56	37.92			
Ohio[c]	7	63.4	57.1	46.8				
N. Dak.[d] ...	4		33.4	33.7	29.2	28.6	23.2	17.9

[a] Morrow, G. E., and Gardner, F. D. "Corn and Oats Experiments." *Ill. Agr. Expt. Sta. Bul. 31.* 1893.

[b] Latta, W. C., and Anderson, W. B. "Field Experiments with Corn." *Ind. Agr. Expt. Sta. Bul. 77.* 1899.

[c] Hickman, J. F. "Experiments with Corn." *Ohio Agr. Expt. Sta. Bul. 18.* 1890.

[d] Shepperd, J. H., and Ten Eyck, A. M. "Corn Culture." *N. Dak. Agr. Expt. Sta. Bul. 51.* 1902.

454. The Date of Planting. In Table *454a* the Arkansas station[21] reports extensive comparisons with a large number of varieties, each planted at regular intervals through a 14-week period.

454a. Average yield of corn, bushels per acre, from different dates of planting. Arkansas.

DATE OF PLANTING	FUNK'S 90-DAY 8 YRS.	MEXICAN JUNE 10 YRS.	PAY-MASTER 7 YRS.	HASTINGS PROLIFIC 3 YRS.	CHAMPION WHITE PEARL 3 YRS.	WEIGHTED AVERAGE 16 VARIETIES
April 1.....	25.2	27.6	32.5	...	37.2	28.2
April 15....	37.2	36.8	39.2	32.7	36.2	34.7
May 1.....	33.7	34.9	35.1	27.4	35.4	32.6
May 15....	28.6	32.5	30.7	30.0	33.0	27.4
June 1.....	25.7	30.4	30.0	29.2	29.6	25.4
June 15....	25.7	32.2	31.4	23.5	28.4	24.9
July 1.....	18.9	26.6	26.2	19.9	21.2	20.3
July 15....	16.3	29.4	14.9	19.3	....	22.2

In Table *454b* are reported the yields obtained at a number of corn belt stations from planting at different dates.

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[21] McClelland, C. K.—"Effect of Different Dates of Planting Corn on Yields." *Ark. Agr. Expt. Sta. Bul. 222.* 1927.

454b. Date of planting corn and the yield. Summary.

	Date of First Planting	No. of Years	One Week Later	Two Weeks Later	Three Weeks Later	Four Weeks Later	Five Weeks Later
Indiana[a]	May 1 46.72	7	41.99	39.53	41.27	38.56	...
Ohio[b]	Apr. 25 63.86	6	68.49	67.87	54.87	44.32	...
Kansas[c]	Apr. 10 48.4	11	49.9	50.9	50.4	42.5	42.1
Illinois[d]	Apr. 25 48.0	8	60.0	62.0	62.0	61.0	56.0

[a] *Ind. Agr. Expt. Sta. Bul.* 77. 1899.
[b] *Ohio Agr. Expt. Sta. Bul.* 282. 1915.
[c] *Kans. Agr. Expt. Sta. Bul.* 238. 1926.
[d] *Ill. Agr. Expt. Sta. Bul.* 42. 1896.

Planting and harvest dates are reported by the Bureau of Statistics, U. S. Dept. Agr. as shown in Table *454c*.[22]

454c. Dates of planting and of harvest for corn. Summary. U. S. Dept. Agr.

State	Date of Planting			Date of Harvesting		
	Begins	General	Ends	Begins	General	Ends
Florida	2–21	3–11	4– 2	8–23	9–23	10–17
Texas	2–27	3–13	4– 4	9– 6	10– 6	11–18
Arkansas	3–18	4– 6	5– 6	9–23	10–14	11– 4
Missouri	4–14	5– 1	5–22	9–23	11– 4	12–16
Illinois	4–30	5–13	6– 2	9–26	10–29	12–10
Indiana	5– 1	5–14	5–31	9–21	10–29	12– 8
Iowa (State)	5– 4	5–13	5–26	10–19	11– 6	12– 6
Minnesota	5–13	5–19	5–30	9– 9	9–17	9–28

455. Supplementary Crops in the Corn Field. In the corn belt soybeans are often planted in the hills with corn for various purposes such as hogging down, sheeping down, or for silage. Soybeans, cowpeas, and velvet beans are used for these purposes in the South, either in the rows with the corn or between the corn rows, usually being planted at the time of the last cultivation. In the central corn belt rape is often seeded broadcast in the corn field at the time of the last cultivation. There has been much discussion regarding the advisability of these practices. The effect of supplementary crops on the yield of corn has been determined at a number of the experiment stations.

Ames[23] reports that corn grown alone produced 48.2 bushels; corn with soybeans, 45.5 bushels; corn with velvet beans, 31.3 bushels;

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[22] Covert, James R.—"Seedtime and Harvest; Cereals, Flax, Cotton, and Tobacco." *U. S. Dept. Agr. Bur. Statis. Bul.* 85. 1912.

[23] Ames, C. T.—"Report from Holly Springs Branch Experiment Station for 1923." *Miss. Agr. Expt. Sta. Bul.* 220. 1923.

2 rows of corn to 1 row of soybeans, 42.5 bushels, and 2 rows of corn to 1 row of velvet beans, 40.2 bushels.

Ferris and Anderson[24] report that corn grown alone made 35.6 bushels per acre; with soybeans, 29.9 bushels; with cowpeas, 29.5 bushels; with velvet beans, 13.6 bushels. Cowpeas alone made 32.2 bushels per acre and when grown with corn, 19.7 bushels; soybeans alone made 12.1 bushels per acre and 6.9 bushels when grown with corn. Velvet beans did not fruit at all when grown alone, and made 21 bushels when grown with corn.

At the Arkansas station,[25] corn grown with cowpeas, soybeans, and velvet beans averaged 33.3 bushels per acre, while corn alone made 46.4 bushels.

Mooers[26] reports that in Tennessee, as a 6-year average, corn alone yielded 49.9 bushels when corn and soybeans produced 32.3 bushels of corn and 17.1 bushels of beans; beans alone, 25.9 bushels. Where cowpeas were grown in place of soybeans, the yield of corn alone was 39.4 bushels; corn and cowpeas in combination, 27.1 bushels of corn and 8.2 of peas, as a 4-year average. Where cowpeas were planted in corn at the last cultivation over a 17-year period, corn without the peas yielded 28.2 bushels of grain and 1.01 tons of stover, and corn with peas yielded 29.4 bushels of grain and 1.08 tons of stover.

Mooers reports that in 8 out of the 17 trials at the Jackson station, cowpeas sown broadcast in corn at the last cultivation either failed completely or made only a light, unprofitable growth.

Rape when seeded in corn at the last cultivation is believed to have very little, if any, effect on the yield of corn, but the success of such seedings is almost entirely dependent upon summer rains. Probably half of them fail to make a profitable return. A few farmers mix a little rape in the corn planter box and get the rape plants in the hill with the corn. This tends to insure a stand of rape but work at the Iowa station indicates a decrease in the yield of corn.

456. Corn and Soybeans. More experimental work has been done with soybeans planted in corn than with other crops.

Etheridge and Helm[27] found that soybeans, when planted with corn at corn planting time, invariably reduced the yield of corn, the reduction increasing with the increase in proportion of beans planted. However, they report as a 5-year average that, acre for acre, the corn and soybean combination, when hogged off, is more valuable than corn alone.

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[24] Ferris, E. B., and Anderson, W. S.—"A Report of Work at the South Mississippi Branch Experiment Station for 1925." *Miss. Agr. Expt. Sta. Bul. 232.* 1925.

[25] Gray, Dan T.—"Thirty-eighth Annual Report." *Ark. Agr. Expt. Sta. Bul. 215.* 1926.

[26] Mooers, C. A.—"Influence of Cowpeas Crop on Yield of Corn." *Tenn. Agr. Expt. Sta. Bul. 137.* 1927.

[27] Etheridge, W. C., and Helm, C. A.—"Corn and Soybeans." *Mo. Agr. Expt. Sta. Bul. 220.* 1924.

Park, Willard, and Borst[28] report the yield of corn alone, of soybeans alone, and of corn and soybeans when grown in combination. As a 3-year average, corn alone produced 58.7 bushels per acre; when grown with soybeans, 53 bushels, with 8.4 bushels of beans; while the beans when grown alone yielded 22.3 bushels. In 1919, a fairly normal year, the yield of corn was lowered 5.3 bushels by the presence of the beans, while in 1920, which was very moist, the beans did not reduce the yield of corn at all, although a third of a full crop of beans was produced in addition to the corn. In 1921 there was a severe drouth, and the beans reduced the yield of corn 12.5 bushels per acre.

As a 3-year average, the yields of air-dry material for silage were: for corn alone, 3.59 tons; for soybeans alone, 2.79 tons; and for the combination of corn and beans, 4.3 tons, of which 3.48 tons was corn and 0.82 ton soybeans.

FIG. 94.—Hogging down corn and soybeans. *Under what conditions does the planting of soybeans in corn decrease the yield of the corn and how much? When corn is planted to be hogged off is the planting of beans with the corn a profitable practice?*

These investigators conclude that under average Ohio conditions the combination will produce more feed per acre than corn alone both for silage and for hogging down.

Slate and Brown[29] planted a combination of corn and soybeans and increased the yield of green forage approximately 1 ton and the dry matter about 500 pounds per acre over corn alone. The corn and soybeans cut for silage contained 670 pounds of protein per acre, while the corn alone contained 550 pounds, narrowing the nutritive ratio from 1 to 13 to 1 to 9.8. Drilling was decidedly better than checking. A stalk of corn to 3 of beans per 12 inches of row gave the largest total yield of green and dry matter and of protein. They state that under Connecticut conditions planting soybeans in the corn will add $10.00 per acre to the value of the silage produced.

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[28] Park, J. B., *et al.*—"Growing Soybeans in Corn." *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 7, Nos. 5 and 6, pp. 76-78. May-June, 1922.

[29] Slate, W. L., and Brown, B. A.—"Corn and Soybeans as a Combination Crop for Silage." *Conn. [Storrs] Agr. Expt. Sta. Bul. 133.* 1925.

Ayres[30] reports yields of corn and soybean combinations at the Delta, Mississippi, station, as shown in Table *456a.*

456a. Yield of grain from corn-soybean combinations as compared with corn alone, yields in bushels per acre, four-year average. Delta, Miss.

	CORN	BEANS	BOTH
Corn 24″, beans between hills at planting	17.7	7.17	24.87
Corn 24″, beans between hills 3 weeks later ..	22.5	4.70	27.20
Corn 24″, beans in alternate rows	15.10	5.93	21.03
Corn 12″, beans in alternate rows	16.00	5.27	22.27
Corn alone 24″ in the drill	24.20	...	24.20

At the Iowa Station, Wilkins and Hughes[31] report that when corn and beans were planted together the average yield of corn was 46.3 bushels per acre and 248 pounds of beans, as compared with 53.9 bushels of corn when planted alone. The beans produced 58.1 per cent as many pounds as they reduced the yield of corn. These are the average yields for all comparisons made during a 7-year period with 1033 experimental plantings on 16 fields. The average number of plants per hill at harvest was 2.75 of corn and 3.87 of beans. The varieties used were the Reid Yellow Dent corn and the Manchu bean.

When the Peking variety was planted with corn for silage, the yield was 11.93 tons, of which 15.8 per cent was soybeans, as compared with 11.29 tons per acre when corn was planted alone. These silage yields are average for 17 fields over a 6-year period with 898 experimental plantings considered. The average number of corn plants per hill was 2.82 of corn and 3.98 of beans.

Weaver[32] reports work at the Missouri station on hogging down corn. He found that hogs harvesting corn and soybeans produced more pork per acre, made more rapid gains and required less feed per 100 pounds of gain than did hogs harvesting corn alone. He found, however, that corn and soybeans were not as efficient as corn and tankage.

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[30] Ayres, W. E.—"Soybeans." Delta Branch Experiment Station. *Miss. Agr. Expt. Sta. Bul. 227.* 1925.

[31] Wilkins, F. S., and Hughes, H. D.—"Corn and Soybeans." *Iowa Agr. Expt. Sta. Bul.* (in press). 1930.

[32] Weaver, L. A.—"Hogging Down Corn and Soybeans." *Mo. Agr. Expt. Sta. Bul. 224.* 1924.

Robison[33] states that pigs on standing corn containing soybeans usually gain more rapidly and produce more gain per bushel of corn consumed than pigs on standing corn alone; but, because of the reduction of corn brought about by the presence of soybeans, it is questionable whether any more gain in live weight per acre results from the combination than from standing corn alone.

CULTIVATION

All phases of corn cultivation have been considered in Chapters VI and XI.

HARVEST

457. Methods of Harvesting Corn. In the United States, harvesting methods vary to a considerable extent with the section of the country. Corn may be harvested (1) by picking the ears from the standing stalk by hand or by machine; (2) by cutting the stalk and shocking for husking later; (3) by cutting the stalk green and feeding immediately; (4) by cutting and putting into a silo, or (5) by turning the stock into the field and letting them gather the crop.

Piper *et al.*[34] in 1919 estimated the acreage of corn used for various purposes or harvested in different ways as shown in Table *457a*.

457a. Acreage of corn harvested in different ways.

METHOD OF HARVEST	THOUSANDS OF ACRES
For grain, mostly shucked from standing stalks	87,772
For fodder, cut and shocked to cure, or fed green	4,500
For silage	3,924
For pasturing off	2,350
Sweet corn	272
Total crop of 1919	98,818

458. Shucking, Picking, and Jerking. In a 10-hour day under central Illinois conditions[35] an average experienced husker equipped with a team and wagon shucked 83.8 bushels in corn yielding 42 bushels to the acre; 87.8 bushels in corn yielding 50 bushels, and 93.4 bushels in corn yielding 60 bushels to the acre. One man and 5 horses with a mechanical picker harvested 360 bushels in a 10-hour day.

A common practice in the South is to "jerk" or snap the ears from the standing stalks storing the grain with the husks on. A man does not snap as much in the South in one day as is shucked per day in the corn belt proper.

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[33] Robison, W. L.—"Soybeans in Corn for Hogging Down." *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 9, Nos. 5 and 6, p. 80. May-June, 1924.

[34] Piper, C. V., *et al.*—"Our Forage Resources." *U. S. Dept. Agr. Yearbook 1923*, p. 344.

[35] *U. S. Dept. Agr. Yearbook* 1922, p. 1057.

459. The Mechanical Corn Picker. Reynoldson[36] stated that in 1925 there were more mechanical pickers in eastern South Dakota and southeastern North Dakota than in any other section of similar size in the corn belt. The picker does a very good job if the corn stands up well, and a fairly good job when the corn is lodged crosswise. The picker wastes the least corn and does the cleanest job of husking in corn that is slightly damp. Under such conditions few ears are left in the field, practically all of the husks are removed from the ear, and the stalks are not broken loose from the ground by the passage of the machine. Reynoldson gives the work per day for the mechanical corn picker under Dakota conditions with different sized crews and with different methods of unloading and handling the corn in Table *459a.*

459a. Rate of work per day for mechanical corn picker with different sized crews. Dakota.

Picker Crew		Hauling Crew		Method of Unloading	Yield per Acre	A. per Day	Bus. per Day	Hrs. per Day	Bus. per Hr.	Bus. per Man
Horses	Men	Horses	Men							
5	1	2	1	Hand	26	6.25	163	8.50	20	82
5	1	2	1	Elevator	32	6.50	203	8.00	15	102
6	1	2	1	Hand	25	6.75	164	8.50	19	82
5	1	4	2	Hand	29	7.50	220	9.00	25	73
5	1	4	2	Elevator	24	7.00	241	8.75	29	80
6	1	4	2	Hand	30	7.00	206	8.75	23	69
6	1	4	2	Elevator	29	8.00	236	9.00	27	79

460. Corn Fodder. The entire corn plant, including the ears, is referred to as corn fodder. When the ears are removed from the fodder, the stalks and leaves which remain are called stover. Very little corn is cut for fodder or for the stover in the western part of the corn belt, but in the eastern states and certain sections of the South the majority of the corn crop is cut and shocked in the field. Corn is usually cut when the kernels are well dented and hard and when the lower leaves have started to turn brown. The corn may be cut for fodder by hand with a corn knife, a sled or platform cutter, or a corn binder. It has been estimated that 1 man will cut and shock by hand 1.4 acres per day in central Illinois, and for the United States 1.6 acres per day. A corn binder and a crew of 1 man and 3 horses can cut 8.2 acres per day and 2 men can shock the bundles on 7.2 acres or 3.6 acres per day per man. It has been estimated also that 2 men, with 1 horse and a platform cutter or sled cutter, can cut 5.3 acres per day.[37]

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[36] Reynoldson, L. A.—"Mechanical Corn Picker in the Corn Raising States." *U. S. Dept. Agr. Yearbook* 1926, pp. 521-522.

When cut, the bundles are cured in shocks and later hauled and stacked in a convenient place for feeding. Sometimes the ears are husked by hand in the field from the shocks, or the fodder is run through a shredding machine where the ears are husked and the fodder is torn up into small pieces.

461. Topping and Pulling. In certain sections of the South topping the corn for fodder has been, and still is, the common practice. The stalk is cut off just above the ear and shocked in the field. Sometimes the leaves are stripped from the stalk by hand and cured as fodder. This is called "pulling fodder."

Tracy and Lloyd[38] found that the removal of the tops when the ears were well glazed resulted in a marked decrease in yield of grain, for which the value of the tops did not nearly compensate. Hunt[39] removed the tops when the ears were dented with similar results. Duncan found that the mutilation of the leaves when the ear was in the soft dough stage resulted in a reduction in yield of from 6 to 8 bushels per acre, a loss several times greater than the value of the leaves when "pulled" for fodder.

Erwin and Haber[40] topped sweet corn in the denting stage and found that the average weight of ear was decreased approximately 4 per cent.

462. Pasturing Off the Corn Crop. Corn may be pastured off by beef cattle, sheep, or hogs. If beef cattle are used, hogs should be used in connection as otherwise there would be a large waste of corn. Harvesting corn with cattle is not a common practice as the waste is large and the tramping of the soil in wet weather is often detrimental. The usual method is to pick the corn and then allow cattle to clean up the field afterwards and get what pasture they can from the stalks. The practice of turning lambs into the corn field seems to be growing in the corn belt. Some men turn in only enough to clean up the weeds and lower leaves of the corn; others are having the lambs harvest the entire crop, sometimes following with hogs to clean up any feed that may be left.

463. Hogging Down Corn. Hogging down corn has proven a very satisfactory and efficient method of harvesting the crop.

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[37] *U. S. Dept. Agr. Yearbook 1922*, p. 1057.

[38] Tracy, S. M., and Lloyd, E. R.—"Corn." *Miss. Agr. Expt. Sta. Bul. 33.* 1895.

[39] Hunt, T. F.—"Cultural Experiments." *Penn. State College. Ann. Rpt.* 1891.

[40] Erwin, A. T., and Haber, E. S.—"Sweet Corn Seed Studies." *Iowa Agr. Expt. Sta. Bul. 250.* 1928.

Robison[41] suggests the use of standard corn varieties rather than early maturing varieties due to the fact that any gain due to the early maturity is partially or wholly offset by smaller yields and consequently smaller increases in weight per acre. When tankage or similar feeds were used, 10 pigs averaging 75 to 100 pounds in weight ate about a bushel of corn per day or harvested an acre in approximately as many days as the yield in bushels. Robison found that soybeans in the corn were less efficient than tankage for supplementing corn when hogged off. Standing corn, rape, and tankage produced more rapid growth and slightly smaller gains per bushel of corn consumed than standing corn, soybeans, and tankage. Harvesting the corn and feeding consistently gave a larger return per bushel of corn than was obtained where the corn was hogged down. Usually the difference was more than sufficient to pay for the additional cost of the harvesting under normal conditions. The chief advantage in hogging down corn is the labor it saves; the chief disadvantage is the necessity of marketing corn through hogs at the time of year when the price is usually low.

Williams[42] reports that the average return per bushel of corn was 83 cents when it was hogged down and 96 cents where it was hand fed. Hand feeding costs were 13.5 cents per bushel over that hogged down, giving a net return of 82.5 cents per bushel.

Henry and Morrison,[43] summarizing the work at the Minnesota, Iowa, Indiana, and Ohio stations comparing the results obtained from corn hogged down as compared with yard-fed corn, report the average daily gain at 1.59 pounds and 1.50 pounds, respectively, and the pounds of concentrates per 100 pounds of gain as 478 and 511 pounds, respectively.

464. Carrying Capacity when Hogging Down. Edwards and Brown[44] found that in Michigan an acre of corn and soybeans carried 7 pigs for 30 days, while corn and rape and corn and tankage each carried 7 pigs for 34 days. The average daily gain per pig was 1.6 pounds for corn and rape, 1.7 pounds for corn and soybeans, and 1.5 pounds for corn and tankage.

The number of pig days of pasture will vary with the size of pigs and the acre yield of corn as well as the supplements which may be fed. Gaumnitz *et al.*[45] report from the Minnesota station the number of days required for a certain number of pigs to clean up an acre of corn yielding 40, 50, 60, and 70 bushels per acre.

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[41] Robison, W. L.—"Hogging Down Corn." *Ohio Agr. Expt. Sta. Bul. 398.* 1926.

[42] Williams, C. G.—"Forty-first Annual Report of the Ohio Agricultural Experiment Station for the year ended June 30. 1922." *Ohio Agr. Expt. Sta. Bul. 362.* 1922.

[43] Henry, W. A., and Morrison, F. B.—*Feeds and Feeding*, p. 629, 18th Edition. Henry-Morrison Co. Madison, Wis. 1920.

[44] Edwards, W. E. J., and Brown, G. A.—"Hogging Down Corn." *Mich. Agr. Expt. Sta. Quart. Bul.* Vol. 8, No. 4, pp. 171-173. May, 1926.

464a. Number of pigs and time required to hog down an acre of corn. Minnesota.

No. 125 lb. Pigs	Days Required When Corn Yields			
	40 bu.	50 bu.	60 bu.	70 bu.
20	15	19	23	26
40	8	9	11	14
60	5	6	8	9
80	4	5	6	7

STORAGE

465. Shrinkage of Ear Corn in Cribs. Shrinkage of ear corn in cribs is reported under Chapter XXXIII on Marketing. (903.)

466. Corn Cribs and Cribbing. Most corn cribs are of wood with slatted siding, usually 8 feet wide and of varying lengths. Cribs more than 8 feet wide are likely to be poorly ventilated in the middle. In the event of large crops or in sections where corn is mostly grown for market, the crop is often stored in temporary cribs made with wire or lath fence material. Metal, hollow tile, and cement stave cribs are becoming more and more general as growers are coming to realize more fully the loss resulting annually as a result of improper storage. Many of these cribs have special ventilating ducts in the middle of the crib, which aid materially in hastening the curing process.

Ordinarily corn is safe to crib when the moisture content has been reduced to 25 to 30 per cent or less. Calculating the capacity of cribs and bins, a bushel of ear corn is estimated to occupy 2.5 cubic feet and shelled corn 1.25 cubic feet. The volume of a bushel of snapped corn; that is, corn with the husks on, varies somewhat, usually occupying about 3.5 cubic feet. Shelled corn weighs 56 pounds per bushel and ear corn 70. There is no standard for snapped corn but 72 pounds is commonly used.

467. Soft Corn. When frost kills the corn before it has fully matured "soft corn" results. In 1902, 1915, 1917, and 1924 soft corn was a serious problem in the northern part of the corn belt. At the time of normal maturity the grain contains approximately 35 to 40 per cent of moisture. Following this there is a gradual loss of moisture from the whole plant until at husking time the moisture in the ear is usually about 20 to 25 per cent.

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[45] Gaumnitz, D. A., *et al.*—"Pork Production." *Minn. Agr. Expt. Sta. Bul. 104.* 1907.

468. Cribbing Soft Corn. Rather soft corn can be cribbed without loss if special precautions are observed. The ordinary corn crib is built to care for corn with 20 to 25 per cent moisture, but the ventilation of this crib is inadequate for soft corn. When corn containing 30 to 35 per cent of moisture is to be cribbed, ventilators should be so placed in the crib that there will not be more than 2 feet between any part of the corn and a freely moving current of air. Several means of ventilation are suggested. Ventilating partitions in the crib are made by placing 2 parallel rows of studding 6 inches or more apart and covering these over with slatted boards or with wire so that air can pass freely from the corn into this ventilating channel. "A"-shaped ventilators may be built and put through the crib. Timbers placed crosswise of the crib give some ventilation, particularly as the corn settles. In many cases the crop may be put in condition so that it is safe to crib by sorting out the ears that are soft. This sorting can be done either by having a partition across the wagon box when picking in the field or the corn may be sorted at the elevator. Corn which is to be cribbed with a high moisture content should be husked clean.

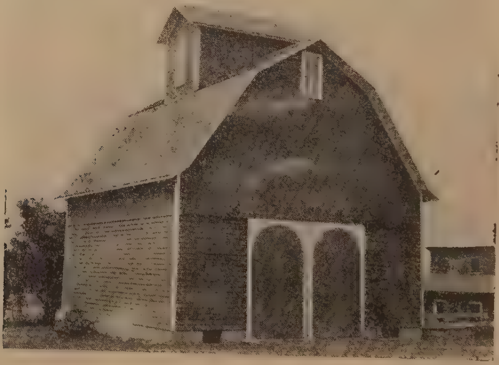

FIG. 95.—A type of corn crib found on many farms. *At what moisture content is it safe to crib corn in the fall? What is the cost per bushel per month to store corn in such a crib as this? Under what conditions is it profitable to hold corn and when can it be sold to best advantage?*

469. Salt and Soft Corn. In some sections farmers have been using salt when cribbing soft corn. Hughes [46] found that salting was of value in retarding fermentation and molds and that 1 pound of salt per 100 pounds of soft corn could be used to advantage. It is reported that stock can use 1 pound of salt per 100 pounds of grain satisfactorily. Two pounds of salt appeared to give noticeably better results than 1 pound but it is probable that this amount of salt cannot be used when the corn is to be fed to livestock. When corn containing a high percentage of moisture is stored, the use of salt will not sufficiently reduce the formation of molds or heating and every precaution should be taken to provide as good ventilation as possible.

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[46] Hughes, H. D.—"Salting Soft Corn." *Iowa Agr. Expt. Sta. Cir. 41.* 1917.

470. Shocking and Ensiling Soft Corn. Occasionally soft corn is cut with a corn binder and placed in relatively small shocks in the field. Fodder and stover are of high quality in a soft corn year, but on many farms the amount of livestock fed is insufficient to handle all of the crop in this way.

Where there is a small acreage of soft corn, the entire crop may be put into the silo. It is possible to fill the silo several times during the year using shocked corn after the first filling. Where large acreages of soft corn occur, it may be advisable to put only the ears in the silo. Ensilage made from ears only is fed as a concentrate instead of a roughage. In this method the ears should be cut into pieces not more than 1 inch in length and smaller pieces would be much better. Evvard[47] states that water should be added with the ear corn and the silage covered over with cheap material such as shredded stover in order to prevent loss of valuable feed in the top of the silo.

471. Drying Soft Corn in the Crib. Corn to be dried by forced ventilation in the crib should be free from husks and silks as these prevent the circulation of air in the crib. Ventilating units are placed down the middle of the crib and connected with a fan by means of a conduit. If the crib floor is not tight, building paper should be laid on the floor to prevent the loss of warm air through the floor. A forced current of air without artificial heating will aid in drying soft corn and will prevent heating if the weather is not cold or damp. Heated air will carry a much higher per cent of moisture than air at ordinary temperatures.

Hughes[48] reports reducing the moisture in corn from over 30 per cent to less than 10 per cent in 24 hours at a fuel and power cost of 3 cents per bushel.

472. Feeding Soft Corn. Feeding soft corn is the most logical method of disposition. Evvard states[49] two essential precautions in feeding soft corn: (1) feed early while the quality is still good and

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[47] Evvard, John M.—"The Soft Corn Problem." *Iowa Agr. Expt. Sta. Cir. 40.* 1917.

[48] Hughes, H. D. "Drying Soft Corn." *Wallace's Farmer*, Vol. 43, No. 11, p. 486. Mar. 15, 1918.

[49] Evvard, John M.—"The Soft Corn Problem." *Iowa Agr. Expt. Sta. Cir. 40.* 1917.

(2) feed often, 2 or 3 times per day. He states that moldy corn is dangerous for horses and young sheep, but hogs may be allowed to eat what they will. Evvard found that on the basis of the dry matter content cattle did practically as well on the somewhat soft corn as on the hard, two-year-old, mature corn; the dry matter in the somewhat soft corn proved to be equally as efficient as in fully mature corn.

473. Water in Soft Corn. The relationship between the moisture in the corn and the number of bushels of ear corn of that moisture content required to have the same amount of dry matter as 100 bushels of 10 per cent moisture corn is reported in Table *473a*.

473a. Relative dry matter equivalent of soft corn.

MOISTURE IN CORN GRAIN; PER CENT	MOISTURE IN COB AT CORRESPONDING TIME PER CENT	POUNDS OF EAR CORN REQUIRED TO HAVE THE SAME AMOUNT OF DRY MATTER AS 100 POUNDS OF 10 PER CENT MOISTURE CORN
10	10	100.00
15	22	107.50
20	35	116.92
25	45	127.42
35	55	148.92
50	60	187.65
60	65	230.46

474. Corn Silage. The handling of corn for silage is discussed fully in Chapter XVII.

LABOR COSTS

475. Labor Requirements of Corn. A great deal of attention has been given in recent years to the matter of reducing the labor requirement in corn production. Falconer[50] reports that for 1907 to 1912 the average total labor required to grow an acre of corn was 36 hours, while in 1920 to 1924 it was 25. Between these two periods the labor requirement for seedbed preparation was reduced 1.82 hours per acre; labor for planting, 0.13 hour; labor for cultivation, 2.78 hours; and other man labor, 6.27 hours per acre. The labor required to grow and harvest an acre of corn with different means of harvesting employed is reported from the Ohio Station[51] in Table *475a*. (69, 253, 292a.)

Listing corn where this method can be employed successfully has generally been regarded as most economical in labor requirement.

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[50] Falconer, J. I.—"Labor Requirements for Corn Production in 1907-1920 vs. 1920-1924." *Ohio Agr. Expt. Sta. Bi-mo. Bul.* Vol. 12, No. 1, p. 31. Jan.-Feb., 1927.

[51] Goddard, L. H., and Elser, W. L.—"Labor Cost of Producing Corn in Ohio." *Ohio Agr. Expt. Sta. Bul. 266.* 1914.

475a. Hours of labor required to produce an acre of corn and to harvest in various ways. Ohio.

WHEN GRAIN IS HARVESTED BY	NUMBER OF FIELDS	AVERAGE SIZE OF FIELDS	HOURS OF LABOR PER ACRE		HORSE HOURS USED PER HOUR OF MAN LABOR
			Man	Horse	
Picking	108	12.97	48.18	55.44	1.15
Hogging off	17	6.91	23.38	41.21	1.76
Put in silo	16	7.24	57.21	68.52	1.20
Part labor contracted[a]	36	19.11	43.96	55.45	1.26

[a] $1.27 per acre additional for contract labor.

The days of man labor required to raise 100 acres of listed corn is reported by Selby[52] as 42, and for surface planted corn as 75; the horse labor, 158 for listed corn, and 258 for surface planted corn.

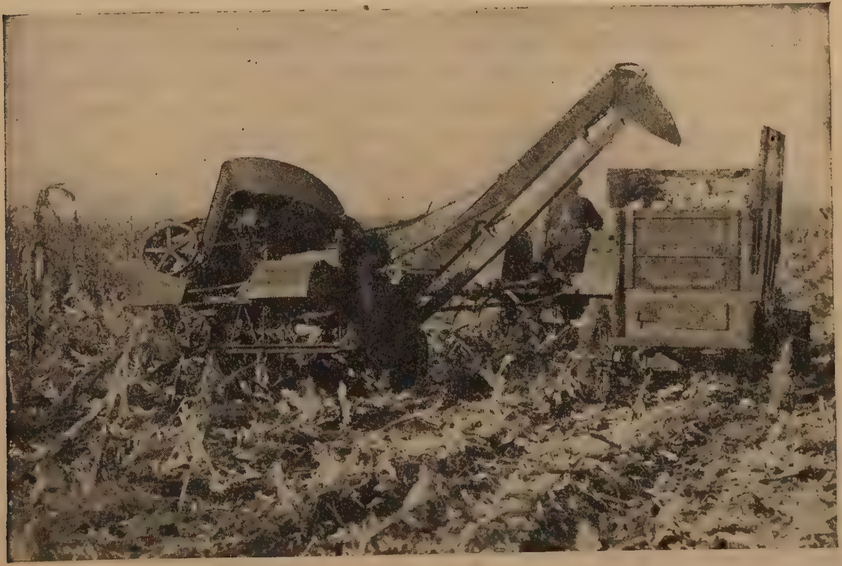

FIG. 96.—The number of mechanical corn pickers in use is increasing rapidly each year. *What is the relative cost of harvesting with such a picker as is shown here and of shucking by hand? Under what conditions is the purchase and use of a corn picker justified?*

476. Labor Required in Harvesting Operations. The labor required per acre for different harvesting operations is reported from Ohio[53] as shown in Table *476a*.

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[52] Selby, H. E.—"Big Scale Corn Raising in Montana." *Mont. Agr. Expt. Sta. Bul. 171.* 1925.

[53] Falconer, J. I., and Dowler, J. F.—"Variations in Costs of Producing Corn, Wheat, and Other Crops in Greene County, Ohio." *Ohio Agr. Expt. Sta Bul. 396*, p. 257. 1925.

476a. Corn: standard labor requirements for harvesting. Ohio.

Operation and Implement Used	Labor per Acre		Acres Covered in Ten-Hour Day
	Man Hours	Horse Hours	
Cutting, 3 horses	1.3	3.9	7.7
Cutting, 2 horses	1.5	3.0	6.6
Cutting by hand	6.5	...	1.6
Shocking after a binder	2.5	...	4.0
Husking from stalk, 1 man and team, 50 bu. yield	6.3	12.6	1.6
Husking from shock, 50 bu. yield	10.0	...	1.0
Hauling and cribbing, 1 man and team	2.0	4.0	5.0
Picking up corn knocked off by binder, 1 man and team 2.3 bu. per acre	.7	1.5	13.7
Shredding, 50 bu. yield	10.0	12.0	1.0
Filling silo (time to cut with binder not included), 7.3 ton yield	17.2	10.0	.6

477. Cost of Growing Corn. The difference between the selling price and the cost of production represents the profit resulting from the growing of a crop of corn. Cooper and Hawley[54] report the cost per bushel of producing corn and the bushel value of the product for various sections of the United States in 1922 and 1923 as shown in Table *477a*.

477a. Bushel cost of producing corn.

Crop and Geographical Division	Yield per Acre—Bushels		Net Cost per Bushel		Value of Products per Bushel	
	1922	1923	1922	1923	1922	1923
North Atlantic States	52	47	0.83	0.87	0.85	0.95
South Atlantic States	30	30	.83	.85	.90	1.03
East North Central	46	44	.56	.61	.65	.72
West North Central	34	35	.53	.54	.57	.63
South Central	26	24	.75	.88	.84	.98
Western	30	29	.67	.66	.78	.73
United States as a whole	35	35	.66	.68	.73	.81

The variation in cost per bushel depends somewhat on the yield per acre. In the corn belt states fields have been grouped according to yield as follows: (1) 7 bushels and under, (2) 8 to 17 bushels, (3) 18 to 27 bushels, (4) 28 to 37 bushels, (5) 38 to 47 bushels, (6) 48 to 57 bushels, (7) 58 to 67 bushels, and (8) 68 bushels and over. The cost per bushel to produce crops on these fields was $8.79, $1.47, 70 cents, 58 cents, 50 cents, 46 cents, and 38 cents, respectively.[55]

[54] Cooper, M. R., and Hawley, C. R.—"Cost of Producing Field Crops, 1923." *U. S. Dept. Agr. Dept. Cir. 340.* 1925.

[55] *U. S. Dept. Agr. Yearbook* 1925, p. 1332.

STUDY QUESTIONS ON CHAPTER XVI

1. How would you prepare the seedbed for corn in the central corn belt? In the dry section? In the cotton belt? Why are different methods necessary?
2. What method would you use in planting in each of the above areas? Why?
3. Compare the yields secured from drilling and from check-planting in the corn belt? Which is used? Why?
4. What determines the best width between rows and number of kernels per hill?
5. What determines the best depth of planting?
6. Is early planting advisable? Explain?
7. Give the more common methods of harvesting corn in the various sections.
8. Rank the different methods of harvesting corn from the standpoint of the amount of labor required.
9. If two different crops having different requirements are grown together, how will this influence the total yield per acre? Why is not this a general practice?
10. A freeze catches your corn on September 25th when the ear has 45 per cent of moisture. How will you harvest and crib? Why? What other methods of handling the crop do you think practical?
11. You have 4000 bushels of new corn in the crib on December 1st, when you are offered 60 cents per bushel. You decide to hold for a year. How many bushels will you have to sell at the end of 12 months and what price will you have to receive to break even?

APPLICATION ASSIGNMENTS ON CHAPTER XVI

1. A level field, free of weeds, is to be used for corn. Will you drill or check the crop? Why?
2. On your average soil, planting corn three kernels per hill in hills 3.5 feet apart, or drilled in rows 40 inches apart and plants 12 inches apart in the row, have given best yields. You are planting corn on much richer land this year. How thick will you plant? Why?
3. A field to be planted to corn is cloddy and needs a rain in order that the clods may be broken by harrowing. It is now the height of the planting season. If you wait for a rain planting may be delayed 10 days. What will you do? Why?
4. You are preparing to plant a corn crop which is to be hogged down and are considering some supplementary crop to plant with the corn. Will you use one? Why? When a supplementary crop is to be used what would you advise?
5. You are planting a field of corn to be used for silage. Will you use a supplementary crop? Why?
6. You are appointed to officiate at a corn-picking contest. Outline the plans and rules by which you would conduct the contest.

7. You have 100 acres of corn to pick each year and are considering the purchase of a mechanical corn picker. What considerations influence your decision? Apply the problem to your home farm. Will you buy?
8. You have purchased a corn picker and are considering a change to some other strain or variety of corn and in the method of planting. What changes will you make? Why?
9. You have decided to hog off 20 acres of corn estimated to yield 50 bushels per acre. Outline the method you will use in hogging this field down in order to avoid undue waste.
10. A freeze on October 1st killed your corn when the ear had 45 per cent of moisture. Weather conditions have not been good for drying the corn since. How will you handle the crop?
11. A man offers you 1000 bushels of corn with 40 per cent moisture in it for feed. No 3 corn is worth 75 cents per bushel. What can you afford to pay for this corn?

CHAPTER XVII

SILAGE

Silage is finely chopped green material in which a certain amount of fermentation has taken place in the absence of free air. Ensile, technically speaking, is a verb meaning to prepare for and place in a silo. A silo is the container in which silage is stored. The terms ensilage and silage have been rather loosely applied and, in common usage, are practically interchangeable. Corn has been used almost to the exclusion of other crops in the making of silage, though sunflowers are used to some extent in the Northwest, while other crops are used in a limited way. For information on the results secured from the planting of supplementary crops with corn for silage see **455** and **456.**

478. Changes Brought About in Silage. The silaging process is very similar to the heating in hay, sweating in grain, and other similar changes. When the green, chopped material is first placed in the silo the temperature normally rises rather quickly to between 85 and 90 degrees F. except near the surface where the fermentation processes are more intense owing to the presence of air. The heating results from respiration or fermentation, in which process carbon-dioxide is formed. **(86.)**

479. Iowa Silage Studies. Lamb[1] found that the more immature the corn the greater the amount of acid produced. Acids are formed chiefly at the expense of the sugars. During the first few days after filling the silo, the most noticeable change is the inversion of the sucrose sugar. The total sugar content decreases in amount from the time of filling the silo until a minimum is reached in about 3 weeks. Oxygen in the silage is used up very early in the process of fermentation and is driven out by the carbonic acid gas. From this early stage on, the presence of air (oxygen) is fatal to the proper preservation of the silage because air permits the development of molds. The next change noticed in the silage making process is the change in color, the more or less pleasant aromatic odor, and sour taste. The acids formed are chiefly lactic acid which is the acid form found in sour milk, and acetic acid, the acid of vinegar. The total amount of acid formed is usually between 1 and 2 per cent of the weight of the silage. In the presence of this acid, fermentation is impossible, for the bacteria which cause decay cannot live and work in such an environment. If air is allowed to enter, molds develop and counteract the acidity, thus allowing the putrefactive bacteria to thrive again. This accounts for the decayed silage on top of the silo. Another characteristic is the breaking down or partial digestion of protein matter. This is somewhat of a pre-digestive process and does no harm since little or no nutritive value is lost. The various changes take place with the greatest rapidity during the first 5 days and are practically complete at the end of 10 or 12 days. The causes of silage fermentation, according to Lamb, are as follows: (1) a plant enzyme digests the starch and gives a preliminary increase in some cases of sugar content; (2) a second enzyme breaks down cane sugar into simple sugar; (3) acid forming bacteria are the agents which form most of the acid from the sugar; (4) part of the alcohol is formed by the plant enzymes, while more is formed later by yeasts; (5) a part of the protein is digested by plant enzymes and some by bacteria, and the heat generated in the silaging process seems to be due to these two agencies; (6) the evolution of carbonic acid gas seems to be due primarily to plant enzymes, though bacteria and yeast furnish part of it.

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[1] Lamb, A. R.—"Silage and Silage Fermentation." *Iowa Agr. Expt. Sta. Bul. 168.* 1916.

480. Wisconsin Silage Studies. Peterson, Hastings, and Fred[2] have studied the principal changes in the making of silage. They have reported that the oxygen disappears in from 4 to 5 hours; the carbon dioxide increases for about 48 hours, when it comprises from 60 to 70 per cent of the silo gases. The temperature continues to increase for 15 days and then falls off somewhat but continues at a high level for 60 to 70 days. The fermentation products appear in marked quantities simultaneously with the appearance of large numbers of bacteria 24 to 48 hours after ensiling. They state that it is probable that the bacteria are the chief agents involved in the production of ethyl alcohol and acetic and lactic acid in silage. These products originate mainly from sugar, but a marked destruction of pentosans and starch indicates that the latter substances are also converted in part by the fermentation process. As the acid increases there is a decided change in the bacterial flora. The conditions for growth of the lactic acid bacteria in the silo are excellent, and they reach unusually large numbers. This huge mass of microörganisms exists for only a short time, when they begin to die.

481. Changes in Composition Due to the Silaging Process. Ohio. At the Ohio station a small sack of ground corn was buried in the silage and later the composition compared with similar corn not subjected to the ensilaging action. The per cent of protein found in the ensilaged corn meal as compared with the meal not ensilaged was 9.83 and 5.38; the ether extract 2.93 and 5.07; crude fiber, 2.37 and 2.91; ash, 1.18 and 0.89, while the nitrogen free extract was 83.69 and 85.75 per cent, respectively.[8]

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[2] Peterson, W. H., *et al.*—"A Study of the Principal Changes Which Take Place in the Making of Silage." *Wis. Agr. Expt. Sta. Res. Bul. 61.* 1925.

FIG. 97.—Barn and silo equipment on a Minnesota livestock farm. *What conditions warrant the construction of a silo and the labor and other expense necessary in ensilaging crops?*

Determinations of the composition of corn stover before and after ensiling are reported from Ohio in Table *481a*.

481a. Analysis of roughage before and after ensiling.

ROUGHAGE	CRUDE PROTEIN PER CENT	ETHER EXTRACT PER CENT	CRUDE FIBER PER CENT	ASH PER CENT	N. FREE EXTRACT PER CENT
Sample No. 1:					
Before ensiling	4.92	.38	35.11	4.27	55.31
After ensiling	7.67	6.78	29.09	5.78	50.68
Sample No. 2:					
Before ensiling	5.79	1.93	24.99	6.19	61.09
After ensiling	6.16	3.17	32.05	6.20	52.41
Sample No. 3:					
Before ensiling	5.99	2.03	24.89	5.45	61.64
After ensiling	7.59	5.52	27.84	6.03	52.96

482. Losses in Ensiling Corn. Studies reported from 1889 to 1894 showed rather large losses in nutrients when corn was ensiled. More recent studies indicate that the losses are much smaller and this difference is no doubt partially due to differences in the practices employed, particularly the types of corn put in the silo and the stage of maturity when the crop is harvested.

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[8] Perkins, A. E.—"Losses and Exchanges of Material during the Storage of Corn as Silage." *Ohio Agr. Expt. Sta. Bul. 370.* 1923.

In 1924, Stadler *et al.*[4] report a non-avoidable loss of nutrients of 7.59 per cent of the dry matter during the formation of the silage. Compared to this loss in the silo it was found that as an average for 4 different seasons in the field curing of corn the average loss of dry matter was 15.12 per cent.

The amount of digestible nutrients in 100 pounds of various crops when ensiled and when fed in the fresh stage as reported by Henry[5] is shown in Table *482a.*

482a. Analysis of various forages in green state and as silage.

ROUGHAGE	DIGESTIBLE NUTRIENTS IN 100 POUNDS			
	Dry Matter in 100 Lbs.	Crude Protein	Carbo-hydrates	Fat
Green corn fodder	23.1	1.0	13.7	0.4
Corn silage	21.0	1.0	11.4	0.4
Green sorghum fodder	24.9	0.7	14.8	0.7
Sorghum silage	22.8	0.6	11.6	0.5
Fresh red clover	26.2	2.7	13.0	0.6
Clover silage	24.4	2.0	9.6	0.8
Green soybeans	23.6	3.2	10.2	0.5
Soybean silage	27.2	2.8	10.8	0.9
Green cowpeas	16.3	2.3	8.0	0.3
Cowpea silage	21.2	1.8	9.7	0.5
Kentucky bluegrass	31.6	2.3	14.8	0.6
Green oats and peas	22.6	2.4	10.6	0.6
Mangels	9.4	0.8	6.4	0.1
Sugar beets	16.4	1.2	12.6	0.1

GROWING A CORN CROP FOR SILAGE

483. Rate to Plant Corn for Silage. Williams and Welton[6] reported, in 1914, yields of corn at the Ohio station when drilled at different rates as shown in Table *483a.*

The effect of planting different numbers of kernels per hill at the Ohio station is reported in Table *483b;* an average for a 21-year period.[7]

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[4] Stadler, L. J., *et al.*—"Production and Feeding of Silage." *Mo. Agr. Expt. Sta. Bul. 226.* 1924.

[5] Henry, W. A., and Morrison, F. B.—*Feeds and Feeding*, pp. 740 and 742. 18th ed. The Henry-Morrison Company. Madison, Wis. 1922.

[6] Williams C. G., and Welton, F. A.—"Forage Crops: Annual Grasses and Roots." *Ohio Agr. Expt. Sta. Bul. 269.* 1914.

[7] Wallace, H. A.—"What Thick Planting Does to Corn." *Wallaces' Farmer*, Vol. 50, No. 18, p. 641. May 1, 1925.

483a. Rate of planting corn for silage. Ohio.

KERNELS DROPPED EVERY	5-YR. AV. YIELD TONS PER ACRE	TOTAL NUTRIENTS POUNDS PER ACRE
4 in.[a]	15.74	7694
6 in.	14.27	5736
10 in.	13.53	5879
12 in.	12.87	5528

[a] Note was made of a tendency for the corn to lodge when planted 4 inches apart in the drill.

483b. Acre production, in pounds of forage and therms of energy; from planting different numbers of kernels per hill; 21-year average. Ohio.

	NUMBER OF KERNELS PER HILL				
	1 ker.	2 ker.	3 ker.	4 ker.	5 ker.
Stover per acre, lbs.	2114	3005	3643	4030	4481
Ear corn per acre, lbs.	2260	3642	4483	4766	4708
Therms energy in ears	1654	2659	3254	3446	3398
Therms energy in stover	668	950	1152	1275	1417
Total therms energy in plant	2322	3609	4406	4720	4815
Pounds ear corn per 100 lbs. stover	107	121	123	118	107

Other references on rate to plant for silage will be found under the chapter on Corn Production. (450 and 451.)

484. Type of Corn for Silage. One of the questions to receive early and extensive consideration in growing corn for silage was the varieties and types of corn best suited to this particular use of the crop. Particular attention has been given to large, late maturing varieties as compared to varieties which will mature grain in a given locality. Yields in pounds of silage and of dry matter have been reported from a number of stations as shown in Table *484a*.

485. Varieties for Silage. Ohio. The Ohio station[8] has compared a number of varieties of corn, including the standard corn belt varieties and the prolific types from the South. The average yields for a number of years are as shown in Table *485a*.

Hayden and Perkins[9] compared the composition of the silage from the different types of corn grown at the Ohio station. The Clarage corn was cut, on an average, 21 days earlier than the Blue Ridge corn. Blue Ridge corn yielded more dry matter per acre in 4 of the 5 seasons during which the comparison was made. The average differ-

[8] Markley, J. P.—"County Experiment Farms in Ohio." *Annual Reports for 1920 and 1921. Ohio Agr. Expt. Sta. Bul. 361.* 1922.

[9] Hayden, C. C., and Perkins, A. E.—"Field Corn and Silage Corn for Silage." *Ohio Agr. Expt. Sta. Bul. 369.* 1923.

484a. Early and late corn varieties compared for silage; yields in pounds per acre. Summary.

	Type	Source of Variety	Silage	Dry Matter	Digestible Nutrients
Me. Agr. Expt. Sta. Rpt. 1893	Late	So. Dent	34,761	5,036	3,251
	Early	Flint	22,269	4,224	3,076
N. H. Agr. Expt. Sta. Buls. 1 and 2, 1888	Late	Southern	40,900	10,060	....
	Early	Flint	32,000	8,832	....
N. Y. [Geneva] Agr. Expt. Sta. Bul. 16, 1882	Late	Southern	32,400	7,390	....
	Early	Pride of the North	16,800	4,102	....
Mass. Agr. Expt. Sta. Rept. 1906	Late	Eureka	40,800	6,691	4,483
	Early	Pride of the North	27,800	6,255	4,441
Minn. Agr. Expt. Sta. Bul. 40, 1894	Late	Southern	43,000	....	3,887
	Early	Northern	19,500	....	2,911
Ohio Agr. Expt. Sta. Bul. 269, 1914	Late	Blue Ridge	28,960	7,389	....
	Early	Ohio Leaming	19,080	5,861	....
Conn. [Storrs] Agr. Expt. Sta. Bul. 121, 1924	Late	Several varieties	40,600	8,064	....
	Medium	" "	33,000	7,218	....
	Early	" "	24,800	6,491	....
Pa. Agr. Expt. Sta. Rpt. 1892	Late	Southern	32,321	....	3,251
	Early	Northern	18,606	....	3,076

485a. Varieties of corn compared for silage at the Ohio station—yields in tons per acre as cut.

Variety	Length of Test	Tons per Acre at	
		Wooster	Mahoning, All 3-yr. Averages
Clarage	6 yr.	8.14	7.08
Leaming	6 yr.	9.05	8.33
Reid's Yellow Dent	6 yr.	9.39	10.28
Old Virginia (prolific)	7 yr.	11.25	14.18
Eureka (prolific)	6 yr.	11.94	14.62
Blue Ridge (prolific)	7 yr.	10.08	11.58
Boone County White	2 yr.	13.50	....
Amber Sorghum	4 yr.	5.50	5.50

ence was 0.96 tons of 30 per cent dry matter silage per acre. However, the dry matter of the Clarage corn yielded 0.98 per cent more protein and 3.19 per cent more nitrogen free extract, while the dry matter of the Blue Ridge carried 4.09 per cent more crude fiber. The Clarage type seemed a little more palatable than the Blue Ridge. The Ohio investigators report that, all things considered, there is much less difference per acre between the ordinary field corn and the large dent corn than is commonly supposed. Appearance or tonnage at cutting time may be very deceiving because of the larger size and the greater amount of water content in the later maturing corn.

486. Varieties for Silage. Connecticut. White *et al.*[10] report from the Connecticut station that in feeding the early, Pride of the North silage, 28.57 pounds of grain were required to produce 100 pounds of milk, which was 9.7 pounds *less* than was required with the late, Eureka silage, and 4.76 pounds less than with the medium, Leaming silage. Due to the larger acre yields of the late and medium late varieties they produce more food and hence more milk per acre than early maturing corn, although to produce 500 pounds more milk from the late types it is necessary to have 4 tons more of silage. They state that the results justify the use of the late maturing varieties under Connecticut conditions.

487. Varieties for Silage. Maine. Sax and Burgess[11] state that the best early varieties yield approximately 70 per cent as much as the best late varieties in Maine. The late varieties are only two-thirds as valuable ton for ton as varieties which are nearly mature at harvest time, thus making very little difference between the best early and the best late varieties, as far as productive value per acre is concerned.

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[10] White, G. C., *et al.*—"A Comparison of Early, Medium, and Late Maturing Varieties of Silage Corn for Milk Production." *Conn. (Storrs) Agr. Expt. Sta. Bul. 121.* 1924.

[11] Sax, Karl, and Burgess, Iva M.—"Varieties of Ensilage Corn for Maine." *Maine Agr. Expt. Sta. Bul. 330,* 1926.

488. Stage of Maturity at Harvest. Corn is now more mature when harvested for silage than formerly. Wright and Shaw[12] state that the corn should be cut when 80 per cent of the kernels are in the dough stage and 20 per cent in the milk stage. They found also that sunflowers harvested through a considerable period made satisfactory silage and that sudan grass cut at either the early bloom stage or middle to late bloom stage made very satisfactory silage.

Jones and Huston[13] of Indiana have shown that when cut at the usual stage of maturity, the last 20 days of growth before storing in the silo increased the dry matter in the corn plant 45 per cent and the nitrogen free extract 56 per cent.

Hopper[14] reports that for North Dakota conditions corn should not be ensiled much before it has reached the glazed stage although the addition of water may be necessary when cut at this time. At the glazed stage the plant has reached maturity and has attained its maximum production in feeding value as measured by therms of net energy. Ensiling should not be delayed after the glazed stage as the fodder dries out rapidly and there is a loss of dry matter. (369 to 373.)

489. Methods of Harvesting Corn for Silage. Corn for silage may be cut by hand, with a sled or platform cutter, or with a binder. The corn binder is the faster, easier method requiring less than half as much man labor as when the corn is cut by hand. Bundles of corn should not be made too large. In hauling the corn to the silo the use of low trucks decreases the labor required.

At the silo the corn is cut into lengths varying from ½ to 1½ inches. Woodward[15] states that one inch cutting is considered a little too long, for pieces this length will not pack so closely in the silo nor be so completely consumed when fed as the shorter lengths. The longer the pieces the more rapidly can the corn be run through the cutter.

A combination machine or harvester has been used recently. This machine not only cuts the standing crop but also chops the stalks into short lengths in the field and delivers the chopped material into a wagon which is drawn alongside the harvester. The chopped material is elevated into the silo by a blower driven by a small engine or tractor. This method is finding favor with farmers as it reduces the hard labor of filling the silo. One of these harvesters will cover about the same acreage per day as the corn binder.

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[12] Wright, P. A., and Shaw, R. H.—"A Laboratory Study to Determine the Best Time to Ensile Corn, Sunflowers, and Sudan Grass." *Jour. Agr. Res.* Vol. 32, No. 4, p. 332. Feb. 15, 1926.

[13] Jones, W. J., and Huston, H. A.—"Composition of Maize at Various Stages of Its Growth." *Ind. Agr. Expt. Sta. Bul. 175.* 1914.

[14] Hopper, T. H.—"Composition and Maturity of Corn." *N. Dak. Agr. Expt. Sta. Bul. 192.* 1925.

[15] Woodward, T. E.—"The Making and Feeding of Silage." *U. S. Dept. Agr. Farmers' Bul. 578.* 1914.

490. Packing the Silo. In the past, it has been considered very important that silage be distributed uniformly and thoroughly tramped as the silo was being filled. However, in the past few years, a considerable number of men have simply blown the chopped material into the silo, giving no attention to distribution or tramping until the silo was nearly full. This has reduced the labor requirements somewhat. In most cases very satisfactory results have been obtained.

FIG. 98.—A morning in February. *Under what conditions is it practical to silage shocked corn? What is the relative value per ton and per acre of fodder corn and of corn silage? Are there other advantages or disadvantages in putting corn in the silo?*

491. Silaging Shock Corn. Eckles[16] states that putting dry corn into the silo makes satisfactory but not as good silage as corn put in at the proper stage. It is not a practical thing to do except on farms where a water system makes it possible to add the necessary amount of water and to do it quickly, as the corn goes in. The amount

[16] Eckles, C. H.—"Shock Corn for Silage." *Mo. Agr. Expt. Sta. Cir. 71.* 1914.

of water to add to corn fodder must be equal pound for pound to the amount of dry fodder put in.

492. Smutted Corn Silage. South Dakota[17] reports a test where 4 cows were fed 2 to 5 pounds daily of smutted corn silage, and 2 pounds of smutted ear corn. All 4 animals calved soon after the close of the experiment. The 4 cows were reported as looking better at the end than at the beginning of the test.

A farmer in Kansas, afraid of the effect of the smut[18] in the corn on his animals, carefully gathered all the smutted ears in the field into a pile. The cattle broke into this enclosure and ate all they wanted of the smut. No injurious effects were noted.

Sunflowers for Silage

Of crops other than corn, sunflowers have no doubt been grown more generally for silage than any other. This crop appears to have considerable value for silage, particularly in the Northwest.

493. Sunflowers in Comparison with Corn for Silage. Vinall reports[19] comparisons of corn and sunflowers at a large number of stations in the northern part of the country from Michigan westward, in which, in every instance, sunflowers considerably outyielded corn as a silage crop in tons per acre, both under dry-land and under irrigated conditions. In many cases the yield of sunflowers was double that of corn. Sweet sorghum under the same conditions yielded practically the same as sunflowers although it was not tried out in as many localities. Vinall states that the very favorable results obtained with sunflowers was probably due to the fact that most of the tests were made in those regions where large growing varieties of corn, suitable for silage purposes, are not adapted to the climatic conditions.

494. Time of Seeding Sunflowers. Atkinson *et al.*[20] recommend that in the higher altitudes sunflowers be seeded as soon as the ground warms up. With seedings made each week from April 29 to June 10 the larger yields were obtained from the earlier plantings.

Putnam[21] reports seedings made May 26, June 2, and June 9 in the upper peninsula of Michigan in which the May 26 planting gave the larger yield.

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[17] Wilson, James W., and Kuhlman, Arthur H.—"Sunflower Silage for Steers, Smutted Corn Silage for Cows." *S. Dak. Agr. Expt. Sta. Bul. 199.* 1922.

[18] Mayo, N. S.—"Cornstalk Disease of Cattle." *Kans. Agr. Expt. Sta. Bul. 58.* 1896.

[19] Vinall, H. N.—"The Sunflower as a Silage Crop." *U. S. Dept. Agr. Dept. Bul. 1045.* 1922.

[20] Atkinson, Alfred, *et al.*—"Growing and Feeding Sunflowers in Montana." *Mont. Agr. Expt. Sta. Bul. 131.* 1919.

[21] Putnam, G. W.—"Sunflower Experiments." *Mich. Agr. Expt. Sta. Quart. Bul.* Vol. 3, No. 2, p. 50. Nov., 1920.

495. Rate and Method of Planting Sunflowers. Atkinson *et al.*[22] report a 2-year test of rate of seeding sunflowers at the Montana station as shown in Table *495a*.

495a. Width of sunflower rows and the yield per acre. Montana.

Rows Inches Apart	Seed per Acre Pounds	Height of Plants Inches	Green Forage per Acre-Tons
8	30	101	39.8
20	12	96	32.5
24	10	93	26.7
30	8	112	33.6
36	5	112	44.1
42	4	102	23.0

Atkinson *et al.* also planted in hills and drilled with the rows different distances apart.

495b. Method of planting sunflowers compared. Montana.

Method of Planting	Seed per Acre Pounds	Height Inches	Green Forage per Acre-Tons
Rows 20 in., drilled	12	96	32.5
Rows, 20 in., hills 20 in.	7	100	25.6
Rows 30 in., drilled	8	112	33.6
Rows 30 in., hills 4 in.	9	112	43.4
Rows 30 in., hills 8 in.	6	114	39.6
Rows 30 in., hills 12 in.	4	116	40.8
Rows 42 in., drilled	4	102	23.0
Rows 42 in., hills 42 in.	2	104	18.2

Odland and Henderson[23] report tests in West Virgina, spacing sunflowers 3, 7, 10, 14, and 21 inches apart in the row. They state that the 10-inch spacing gave, on the whole, the most satisfactory plants for handling; but that there was no significant difference in the yield of air-dry material for the different spacings.

Hulbert and Christ[24] found at the Idaho station that thickly planted stands gave the highest yields. In rows 42 inches apart with the plants spaced 3 to 4 inches, 4 to 8, etc., up to 20 to 24 inches, the average yields range from 12.1 tons per acre for the 3- to 4-inch spacing, to 9.1 for the 20- to 24-inch spacing.

Minnesota[25] reports the yield of sunflower silage as a 5-year average when planted at different rates, the plants being spaced 4, 8, and 12 inches in the rows, also check planted, 5 plants per hill. When compared on a uniform moisture basis, the 12-inch spacing and hill planting gave the larger yields. The average yield for a 5-year period was from 16 to 17 tons per acre at harvest.

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[22] Atkinson, Alfred, *et al.*—"Growing and Feeding Sunflowers in Montana." *Mont. Agr. Expt. Sta. Bul. 131.* 1919.

[23] Odland, T. E., and Henderson, H. O.—"Cultural Experiments with Sunflowers as Their Relative Value as a Silage Crop." *W. Va. Agr. Expt. Sta. Bul. 204.* 1926.

[24] Hulbert, H. W., and Christ, J. H.—"Growing Sunflowers for Silage in Idaho." *Idaho Agr. Expt. Sta. Bul. 141.* 1926.

[25] Arny, A. C., and McGinnis, F. W.—"Field Crop Variety Trials on the Coon Creek Peat Experimental Fields, 1919-1925." *Minn. Agr. Expt. Sta. Bul. 228.* 1926.

Vass [26] states that the most satisfactory yields were secured at the Wyoming station when the sunflowers were seeded in rows 30 to 36 inches apart and the plants 3 to 6 inches apart in the row. Six to 8 pounds were required to seed an acre. Sunflower silage was found to be equivalent to oats and pea silage in feeding value. Three pounds of sunflower silage was equal to 1 pound of alfalfa hay in feeding tests.

496. The Stage to Cut Sunflowers for Silage. Anthony and Henderson [27] found there was little progressive change in the composition of sunflowers during growth except that there was a tendency for a decrease in carbohydrate content and an increase in fat. They report analyses for various stages of maturity as shown in Table *496a*.

496a. Maturity of sunflowers as related to composition. West Virginia.

STAGE	MOISTURE	ASH	CRUDE PROTEIN	FAT	CRUDE FIBER	CARBO-HYDRATES
Bud	81	1.5	1.4	0.6	5.5	15.8
Full blossom	87	1.6	1.2	0.5	3.9	10.0
Petals dropping	84	1.8	1.1	0.7	5.6	12.5
Dough stage	83	1.7	1.1	1.1	5.0	12.8
Mature	84	1.7	1.6	1.4	4.8	11.0

Shaw and Wright [28] compared the sunflower plant at 7 stages of growth to the corn plant at 9 different stages. The results showed that these 2 plants, when compared upon the moisture free basis, are similar in total protein and albuminoids but that the mature sunflower plant contains smaller proportions of reducing sugars to non-reducing sugars than the corn plant. Sunflower plants contain very little starch as compared to the corn plant.

Nevens,[29] at the Illinois Station, harvested sunflowers at different stages of maturity and reports that cutting when the plants were coming into bloom gave higher milk yield and more palatable silage than cutting when more mature. He found also that sunflowers must be in a much less relatively mature stage than corn at the time they are ensiled, or at least have a higher moisture content in order to insure their preservation as silage.

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[26] Vass, A. F.—"Sunflowers—Their Culture and Use." *Wyo. Agr. Expt. Sta. Bul. 129.* 1921.

[27] Anthony, Ernest L., and Henderson, H. O.—"Sunflowers vs. Corn for Silage." *W. Va. Agr. Expt. Sta. Circ. 32.* 1920.

[28] Shaw, R. H., and Wright, P. A.—"A Comparative Study of the Composition of the Sunflower and Corn Plants at Different Stages of Growth." *Jour. Agr. Res.*, Vol. 20, No. 10, pp. 790-791. Feb. 15, 1921.

[29] Nevens, W. B.—"The Sunflower as a Silage Crop." *Ill. Agr. Expt. Sta. Bul. 253.* 1924.

497. Sunflower and Corn Silage Compared. Joseph and Blish,[30] at the Montana station, determined the digestible nutrients of sunflower silage as compared with immature and mature corn. They found that the sunflower silage ranked higher in digestible crude protein. The digestible nutrients per 100 pounds were greater in silage made from mature corn than from sunflowers. The digestible nutrients per acre, however, produced by sunflower silage were decidedly greater, from 20 to 70 per cent differences being obtained due to the very heavy yields of sunflowers.

Quayle [31] found that in feeding sunflower silage in comparison with corn, during alternate 2-week periods, Shorthorn and Holstein groups of cows showed a slight increase in the production of milk and butterfat when corn silage was used. Considering the cash cost of producing the 2 ensilages in the ratio of their acre yields both lots of cows produced milk and butter fat more cheaply when on sunflower ensilage. All cows were in splendid condition at the close of the experiment.

Jones [32] found in making an abrupt change in feed from either corn or oats and vetch silage to sunflower silage 10 days were required to get the animals onto a full feed of the sunflower silage. They did not clean up sunflower silage as well as they did the other silages. For milk production sunflower silage was found to be about equal to silage made from corn or from oats and vetch.

Vinall [33] summarizes experiments and observations from various stations on the palatability of sunflowers. He states that silage made from sunflowers which are in good condition and at the right stage of development will in most cases be consumed readily by dairy cows and most other kinds of livestock, with the possible exception of horses.

498. Sunflower Growing Other than for Silage. Aside from their value as a silage crop sunflowers are grown in many sections for their seed. A large acreage is grown both in Missouri and in Illinois.

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[30] Joseph, W. E., and Blish, M. J.—"Studies on the Digestibility of Sunflower Silage." *Mont. Agr. Expt. Sta. Bul. 134.* 1920.

[31] Quayle, W. L.—"Comparison of Corn Ensilage and Sunflower Ensilage for Dairy Cows." *Wyo. Agr. Expt. Sta. State Farms Bul. 3.* 1922.

[32] Jones, Roy C.—"Oats and Vetch *vs.* Corn or Sunflowers for Silage." *Ore. Agr. Expt. Sta. Bul. 194.* 1922.

[33] Vinall, H. N.—"The Sunflower as a Silage Crop." *U. S. Dept. Agr. Dept. Bul. 1045.* 1922.

The use of sunflower seed has perhaps reached its highest development in Russia, where several important varieties have been developed. It is grown extensively there for its seed and for its oil, both being consumed as human food. The stalks are utilized as fuel by the peasants. Aside from the use of the seed as human food, sunflowers are valued as a feed for birds and poultry.

There is only a limited number of varieties of sunflowers. The principal variety grown in the United States is the Mammoth Russian. This variety usually grows a single stalk with comparatively few branches and one head 6 to 12 inches in diameter. Varieties of lesser importance are the Texas Silver Queen, Black Giant, Mammoth Russian Giant, Silver and Gold, Common, Double California, and White Beauty.

SORGHUMS AND OTHER CROPS FOR SILAGE

499. The Sorghums and Sudan for Silage. Kansas. Reed and Fitch[34] state that the sorghums, both saccharine and non-saccharine, (sweet and non-sweet) can be used for silage with good results. Corn silage was found to be slightly superior as a milk producer to silage made from either kafir or cane; kafir silage ranked second as a feed for milk cows. The gain in live weight was greater from cane silage pound for pound. In comparing crops for silage it is necessary to consider not only the feeding value but also the yield per acre. They report that under Kansas conditions the greater yield from cane and kafir offset the slight increase in the feeding value of the corn silage. The acidity of cane silage was not as high as that for corn, while kafir was still lower.

Cunningham and Kenney[35] state that sorghum will outyield corn as a forage or silage in any part of Kansas. As an average for 3 years in eastern and central Kansas, sweet sorghum produced 21,420 pounds per acre; blackhull kafir, 14,930 pounds, and pink kafir, 12,251 pounds. In west central Kansas the average yields for a 2-year period were: sweet sorghum, 13,542; blackhull kafir, 12,073, and pink kafir, 9775 pounds per acre.

500. Sorghum for Silage in Missouri and West Virginia. Helm[36] reports, for Missouri conditions, the 2-year average of several of the sorghums and of corn reporting yields per acre in bushels of grain and in tons of green forage.

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[34] Reed, O. E., and Fitch, J. B.—"Sorghum Crops for Silage." *Kans. Agr. Expt. Sta. Cir. 28.* 1914.

[35] Cunningham, C. C., and Kenney, Ralph—"Growing Sorghum in Kansas." *Kans. Agr. Expt. Sta. Bul. 218.* 1917.

[36] Helm, C. A.—"Corn in Missouri." II. Field Methods that Increase the Corn Crop." *Mo. Agr. Expt. Sta. Bul. 185.* 1921.

500a. Yields of corn and sorghums compared. Missouri.

CROP	GRAIN BU. PER ACRE	GREEN FORAGE TONS PER ACRE
Corn	56.6	8.6
Kafir	46.4	8.8
Milo	39.4	7.3
Feterita	36.3	5.7
Sweet Sorghum	32.9	16.7

Hutcheson and Wolfe [37] report the yield per acre for a number of crops; also the dry matter and food constituents.

500b. Yields of various crops in tons per acre; green weight and pounds of dry matter; also food constituents. Virginia.

CROP	GREEN MATERIAL TONS	LBS. DRY MATTER	FOOD CONSTITUENTS, LBS.			
			Protein	Fats	Crude Fiber	Carbo-hydrates
Cockes Prolific corn	16.04	6962.6	647	122	1856	4016
Boone Co. White corn	13.66	6830.0	617	131	1570	4256
Early Amber sorghum	12.12	5398.5	323	154	2104	3877
Mammoth Yellow soybeans	10.15	5239.0	966	207	1639	2007
Whippoorwill cowpeas	8.36	3123.1	522	74	963	1265
Golden millet	5.63	3982.6	278	75	1379	1959

Eckles [38] states that Sudan grass makes excellent silage. The sugar content is sufficient to insure the fermentation at any stage of growth. No special attention to dry matter content is necessary as in the case of legumes.

501. Small Grain for Silage. Jones [39] states that under Oregon conditions oats and vetch yield more tonnage than corn or sunflowers for silage and that silage from this mixture produced slightly more milk than either corn or sunflowers.

Reed and Fitch [40] state that although the silage made from rye alone was not palatable a fair quality of silage results when preserved in large silos. The time to cut rye for silage is when the grain is in the late milk or early dough stage.

Eckles [41] reports that no difficulty was encountered in preserving

[37] Hutcheson, T. B., and Wolfe, T. K.—"Silage Experiments." *Va. Agr. Expt. Sta. Bul. 227.* 1922.

[38] Eckles, C. H.—"Legumes, Sudan Grass and Cereal Crops for Silage." *Mo. Agr. Expt. Sta. Bul. 162.* 1919.

[39] Jones, Roy C.—"Oats and Vetch *vs.* Corn or Sunflowers for Silage." *Ore. Agr. Expt. Sta. Bul. 194.* 1922.

[40] Reed, O. E., and Fitch, J. B.—"Alfalfa Silage." *Kans. Agr. Expt. Sta. Bul. 217.* 1917.

[41] Eckles, C. H.—"Legumes, Sudan Grass and Cereal Crops for Silage." *Mo. Agr. Expt. Sta. Bul. 162.* 1919.

wheat cut in the dough stage. The silage was greenish in color and gave off a sour odor and had a sharp, acid taste but was not unpalatable and was eaten readily by stock. He states that it is possible to preserve rye readily in the silo but that the quality of silage is not satisfactory on account of the general unpalatability of rye forage in any form. When the market conditions and seed supply justify the use of small grain crops for silage no difficulty need be expected and the loss of feeding value in the silo will be no more than for corn. No fear need be felt from the old idea that hollow stemmed plants will not keep in the silo.

502. Alfalfa and Other Legumes for Silage. Most legumes are deficient in fermentable sugars. A number of workers have found difficulty in keeping alfalfa silage, as acid is not produced in sufficient quantity to preserve it.

Upson [42] reports work in Nebraska in which silos were filled with (1) corn, (2) black amber cane, (3) alfalfa and cane mixtures in the proportion of 1 part of alfalfa to 2 parts of cane, (4) equal parts of cane and alfalfa and (5) 2 parts of alfalfa to 1 part of cane. The sorghum cane contains a high per cent of fermentable sugars which makes up for the deficiency in alfalfa. The silos were allowed to stand for 1 year and then were opened. Silage in all except the one containing only alfalfa was found to be in perfect condition. Ensiling is recommended as a means of saving the last crop of alfalfa if the weather conditions are such that it cannot be made into hay.

Reed and Fitch [43] state that alfalfa will make a fairly good quality of silage and will be eaten readily by cattle if fed within a few months after being siloed. They state also that where it is possible to make alfalfa into first class hay, it should not be put into the silo. The addition of carbohydrate material such as corn meal, blackstrap molasses, sweet sorghum stover, and green rye to the alfalfa results in preserving it for a longer time than when alfalfa is siloed alone.

Eckles [44] reports 17 trials of legumes for silage in a period of 4 years. He states that under the proper conditions legume crops may be preserved in the silo with entire success, but as a rule they are best preserved as hay on account of the much greater weight to be handled if put into the silo and the lack of suitable machinery for handling the green crop in the field. If it is advisable to put legumes into the silo, in addition to ordinary precautions, special attention is necessary to insure the proper proportion of dry matter. The dry matter content should be approximately 40 per cent. Legume crops in the stage of maturity to be cut for hay may contain as low as 25 per cent of dry matter and will develop an extremely disagreeable odor if put into the silo with this low amount of dry matter. They recommend that alfalfa be partially cured out in the field after cutting before being put into the silo.

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[42] Upson, F. W.—"Alfalfa Mixtures for Silage." *Nebr. Agr. Expt. Sta. Press Bul. 46.* 1915.

[43] Reed, O. E., and Fitch, J. B.—"Alfalfa Silage." *Kans. Agr. Expt. Sta. Bul. 217.* 1917.

[44] Eckles, C. H.—"Legumes, Sudan Grass and Cereal Crops for Silage." *Mo. Agr. Expt. Sta. Bul. 162.* 1919.

503. Beet Top Silage. Jones[45] reports studies on beet top silage in which he states that the fundamental factors involved in making good corn silage apply in the making of beet top silage. It is not necessary to run the tops through a silage cutter. Beet tops pack into a very dense mass in the silo. The natural earth silo and stacking above the earth are both successful. He states that it is safe to conclude that 1 ton of good beet top silage is equal to ½ ton of alfalfa hay when fed in mixed feeding.

504. Stacked Silage. In the making of stacked silage the corn is cut with the binder at the same stage and in the same way that it would be for putting it into an ordinary silo. As soon as the bundles are cut they are built into a stack about 20 feet in diameter and 20 feet high. The bundles are distributed evenly over the surface with the butts laid to the outside. The material is thoroughly tramped as it is being built and at the finish the center of the stack is filled up as the outside fills up faster than the center. The top of the stack is usually topped with a foot or two of hay or straw to reduce the spoilage of corn as this stack does not turn water readily. The outside of the stack to a depth of a foot or more will spoil but as this consists of the butts of the stalks it is not a serious matter. Favorable results for this method of making silage have been reported from New Zealand[46] and from Australia.[47]

An unfavorable report on stacking bundles of green corn to make stack silage is given by Wilson[48] in South Dakota.

505. Trench Silos. Boss *et al.*[49] state that the trench silo has a number of advantages. It can be constructed with very little cash outlay for material or skilled labor, it can be filled with greater ease and less power machinery, and tramping can be done by horses or other animals. The trench is frost proof, fire proof, and wind proof. No

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[45] Jones, James W.—"Beet Top Silage and Other By-products of the Sugar Beet." *U. S. Dept. Agr. Farmers' Bul. 1095.* 1919.

[46] Dibble, W.—"Silage. The Stack System." *Jour. Agr. (New Zealand).* Vol. 6, No. 6. 1913.

[47] "Stack Ensilage." *Queensland Agr. Jour.* n.ser. Vol. 5, No. 1, 1916.

[48] Wilson, J. W.—"Stacked Green Corn for Cattle." *S. Dak. Expt. Sta. Bul. 229.* 1928.

[49] Boss, Andrew, *et al.*—"Trench Silos in Minnesota." *Minn. Univ. Agr. Ext. Spec. Bul. 100.* 1925.

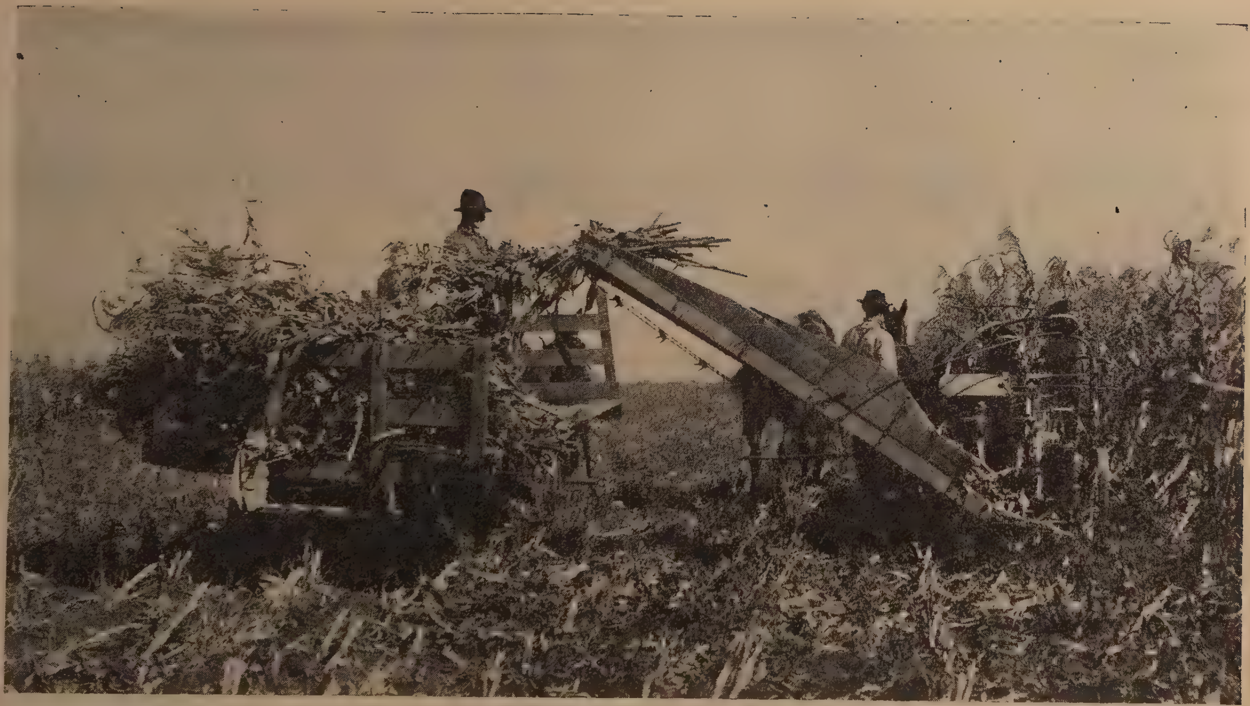

Fig. 99.—Cutting corn for silo with a binder equipped with an elevator attachment which delivers the bundles to the wagon. *In some sections many silos are standing empty year after year. The statement is made that the expense and labor necessary to put the corn into the silo are not justified. Under what conditions might this statement be true? Is it possible for a two-man crew to work efficiently and more satisfactorily than a larger crew in filling the silo?*

machinery for elevating the cut silage is required. A covering of wet straw or green hay is all that is needed. However, the trench silo has certain disadvantages. The walls crumble, water may leak in unless drained away, work with the silage must be done in the open, and there is greater trouble in feeding as the silo may be some distance from the barn. A silo 8 feet in depth and 14 feet wide at the top and 10 feet at the bottom is recommended. The length can be varied to meet the needs of different sized herds.

506. Silage Valuation. Various methods have been suggested for determining the cash value per ton of silage. The price of silage like other products varies with the season. Pearson and Gaines [50] report that a ton of ordinary corn silage contains 354 pounds of digestible nutrients, and that with an average yield, 4.6 bushels of corn would be found in 1 ton of average fodder. If 4.6 bushels of corn contain 211 pounds of digestible nutrients, this leaves 143 pounds of digestible nutrients to come from the roughage part of the silage. It requires from 250 to 280 pounds (270 pounds, average) of prairie, timothy, red top, and red clover hay, to furnish this 133 pounds of digestible nutrients. A ton of silage is equal then to 4.6 bushels of corn plus 270 pounds of hay from the standpoint of nutrition. From the prices of corn and hay the value of the silage can be computed.

A report from the Iowa station [51] indicates that for dairy animals, on the basis of what is consumed, corn silage would be worth $4.50 per ton and fodder $5.05 per ton. One hundred pounds of dry matter in silage was worth 66 cents while the same amount in fodder was worth 32½ cents. The value per acre was $36.00 for silage and $16.21 for fodder for the above values of silage and fodder.

507. Labor Requirements for Putting Up Silage. The *United States Department of Agriculture Yearbook 1922* [52] states that under corn belt conditions in a 10-hour day 1 man and 3 horses cut 6.3 acres of corn with a binder. It required 0.41 hour of man labor to load an acre of corn on a wagon after the corn binder; 7.4 hours hauling and unloading to the cutter; 2.45 hours running the engine and cutter; and 3.01 hours per acre packing the material in the silo. The labor costs vary greatly for different parts of the country. In New York, 4.9 acres was cut in a day with a binder while only 0.9 of an acre was cut when the work was done by hand. The man hours required per acre for loading varied from 7.7 hours in New York to 1.39 hours in Wisconsin and 0.41 hour in Iowa.

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[50] Pearson, F. A., and Gaines, W. L.—"The Evaluation of Corn Silage." *Jour. Amer. Soc. Agron.* Vol. 16, No. 4, pp. 254-256. Apr., 1924.

[51] McCandlish, A. C., and Weaver, Earl A.—"Comparison of Roughages for Milk Production." *Iowa Agr. Expt. Sta. Bul. 212.* 1923.

[52] *U. S. Dept. Agr. Yearbook 1922*, p. 1059.

STUDY QUESTIONS ON CHAPTER XVII

1. What is silage? What takes place in the silaging process?
2. How does the total analysis and feeding value of silage compare with that of the green corn plant?
3. How will the nutritive value of a ton of corn, cut and put into the silo, compare with the same amount cured outside? In what respects will there be a difference?
4. What method of planting corn would you advise in order to secure the greatest production per acre? Why?
5. What type of corn would you advise growing for silage purposes? Would your recommendation depend upon location? Explain.
6. At what stage of maturity should corn be cut for silage in order to secure the greatest food value per acre? What would one lose by cutting later? Earlier?
7. Give instructions for ensiling fodder corn.
8. Consider the advisability, and outline the method of growing sunflowers for silage.
9. Compare sunflowers and corn for silage considering production and value of feed per acre?
10. Which crop would you grow for silage as a second choice to corn or sunflowers? Why?
11. How does sweet sorghum silage compare with corn in quantity and feeding value per acre?
12. What is a fair value per ton for corn silage? How do you arrive at this figure?

APPLICATION ASSIGNMENTS ON CHAPTER XVII

1. On an 80-acre farm with 40 acres in pasture you are running a small dairy, with a total of 20 cattle. You are considering building a silo. What considerations will influence your decision? Will you build the silo?
2. On your farm you are planting 60 acres of Reid Yellow Dent corn expecting to use 12 acres of the 60 for the silo. Ordinarily you plant in hills, 3′6″ each way, 3 kernels per hill. How will you plant the 12 acres for the silo? Why?
3. Reid Yellow Dent will produce 8 tons of silage per acre while under the same conditions a southern prolific corn will produce 11 tons. What considerations will determine which of the two you will plant? Which will you choose?
4. You own a part interest in an ensilage cutter. Each owner hires his own help at the time of filling. You may (a) have the use of the cutter first when the corn is in the early roasting ear stage, (b) wait two weeks, when the corn will be more mature but when labor costs will be much higher or (c) wait 4 weeks when labor will be more plentiful but when the corn may have been frosted. What will you do? Why? If the silage is to be

packed or tramped you will need to hire two more men. What will you do?

5. You are asked to a talk at a farm meeting on the subject—"Crops other than corn for the silo." Write your speech.
6. Your alfalfa has made an unusually heavy growth for a first cutting but due to rainy weather you fear you will not be enabled to cure it as hay. The idea of filling your empty silo with it has been suggested. Will you put it in the silo? Why?
7. You are to talk on "Crops to supplement corn for the silo." Write your speech.

CHAPTER XVIII

THE SMALL GRAINS

The small grains are wheat, oats, barley, rye, rice, and buckwheat. All of these belong to the grass family (*Gramineae*) with the exception of buckwheat which belongs to the smartweed family (*Polygonaceae*). Buckwheat is commonly classed with the cereals which include the small grains and corn, certain millets, and the grain sorghums. The material included in this chapter will have to do particularly with wheat, oats, barley, and rye.

508. Form and Structure of Small Grains. In general the culms or stems are round and usually hollow with solid joints or nodes. New culms may arise from the buds inside the leaf sheath at the basal nodes of the culm. Tillering is explained by the development of these buds. All cereals have alternate, 2-ranked leaves, with each leaf consisting of a leaf blade and a leaf sheath. The sheath encloses the culm and is slit down the side opposite the leaf blade. At the junction of the leaf blade and leaf sheath is a thin membrane called the ligule. At the lower and outer corners of the leaf blade, at the junction with the sheath, are 2 ear-shaped appendages (auricles) which partially or entirely clasp the culm. Auricles are well developed in barley, moderately developed in wheat and rye, but usually lacking in oats. Young wheat plants usually have a number of hairs growing on the auricle (105) (107).

The inflorescence in the case of oats and rice is a panicle, that is, the spikelets are borne on further divided or secondary branches, while the inflorescence of wheat, rye, and barley is a spike with the spikelets sessile on the main axis. In the small grains the central stem or axis to which the spikelets are attached is called the rachis. The spikelets (or units of inflorescence) consist of a much shortened, close jointed, axis having 2-ranked, modified leaves or bracts. The lower 2 of these are known as glumes, outer glumes, or empty glumes. The next above these are the flowering glumes or lemmas, which partly enclose the sexual organs. The other member, the palea, encloses the flower opposite from the lemma. Barley and rice spikelets contain 1 flower each, while wheat, oats, and rye have 2 or more flowers per spikelet. Many flowers fail to develop. In this case they are spoken of as "sterile" or "infertile" flowers. The lemma is supposedly a modified leaf, the lemma proper corresponding to the leaf sheath, the blade either being absent or reduced to form an awn.

Carleton states that in the case of panicles the terminal spikelet of the panicle and its branches flower first, while in spikes the middle spikelet, or those just above the middle are the first to flower. Within the spikelet, the flowering progresses from below upward.

509. The Flower and Its Pollination. The flowers usually contain 3 stamens, an ovary with 1 ovule and a pistil which has 2 plume-like stigmas.

Pope[1] states that the opening of the flower is caused by the absorption of water and consequent swelling of the lodecules, which forces the glumes apart. He observed that the filaments to which the anthers are attached elongate rapidly, a quarter of an inch in 10 minutes. This elongation pushes the anthers up through the opening between the glumes. At the same time the anthers open (dehisce) and about one-third of the pollen falls inside the flower. The anthers are afterwards pushed completely outside the glumes, which close rapidly. The pollen matures and the pistil becomes receptive at the same time. Consequently, selfing is the usual method of fertilization, although cross-fertilization is possible.

Leighty and Sando[2] found the time required for a wheat flower to open fully and the anthers to assume a pendant position varied considerably, but the average of 25 flowers was 3 minutes and 36 seconds, while the time for beginning to complete closing was 26.5 minutes. 86.2 per cent of the flowers bloomed during the daylight; 6.9 per cent, during twilight; and 6.9 per cent, during the night. In the most of the plants, blooming began at the lower half of the uppermost third of the head. The lowest flower in the spikelet usually bloomed first, the others following in order, usually on successive days.

510. Self and Cross-Pollination in Small Grain. Pope[3] reports the estimated per cent of self-pollination and of cross-pollination in the cereal crops as shown in Table *510a*.

Garber and Quesenberry[4] report from studies made in 1921 with winter wheat that there was 1 per cent of natural crossing.

Stanton and Coffman,[5] studying natural crossing in different

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[1] Pope, M. N.—"The Mode of Pollination in Some Farm Crops." *Jour. Amer. Soc. Agron.* Vol. 8, No. 4, p. 214. July-August, 1916.

[2] Leighty, C. E., and Sando, W. J.—"The Blooming of Wheat Flowers." *Jour. Agr. Res.* Vol. 27, No. 5, p. 243. Feb. 2, 1924.

[3] Pope, M. N.—"The Mode of Pollination in Some Farm Crops." *Jour. Amer. Soc. Agron.* Vol. 8, No. 4, p. 225. July-August, 1916.

[4] Garber, R. J., and Quesenberry, K. S.—"Natural Crossing in Winter Wheat." *Jour. Amer. Soc. Agron.* Vol. 15, No. 12, p. 512. Dec., 1923.

[5] Stanton, T. R., and Coffman, F. A.—"Natural Crossings in Oats at Akron, Colorado." *Jour. Amer. Soc. Agron.* Vol. 16, No. 10, p. 657. Oct., 1924.

510a. Method of pollination for common field crops. Pope.

Crop	Self-Pollination	Cross-Pollination
Corn	4-24% probable	Normal
Wheat	Normal	Fraction of 1%
Oats	Normal	Very seldom
Barley	Normal	Practically never, except in 4-rowed barley
Rice	Normal	Probably less than 5%
Rye	Flowers self-sterile, though considerable crossing between flowers on same plant may occur.	Normal
Flax	Normal	Probably less than 1%

varieties of oats, observed the greatest percentage in Iowar, in which an average of nearly 1 per cent was found. The least crossing was observed in Pringle Progress, in which but 0.05 per cent of known crosses was found.

At Morgantown, W. Va., Garber and Quesenberry[6] found that the natural crossing between varieties of the sativa group was comparatively low, only 1 cross being found in a 3-year period in 7742 plants. On the other hand, there was a 0.41 of 1 per cent natural crossing between Fulghum and Victor oats, based on a total of 1708 plants.

511. Tillering. Different varieties and species respond very differently to different environment. Varieties of wheat, for example, when grown side by side under similar conditions show great differences in tillering. Tillering is the branching of the plant at or near the crown so that additional culms arise from one seed. The amount of tillering varies, depending upon the variety and environmental conditions.

Nebraska[7] reports the effect of rate of seeding on the number of stems per plant. Oats planted at the rate of 4, 8, and 14 pecks made 280, 289, and 106 stems per 100 plants in 1907 and 466, 279, and 139 respectively in 1908.

Trowbridge[8] states that the condition of the soil as influenced by rotation and the immediate crop sequence is more important in influencing tillering than the space allotted to each plant.

Grantham[9] found that varieties of wheat varied widely in their habit of tillering and that high tillering varieties not only yielded better under poor conditions but also outyielded the lower tillering varieties under optimum conditions.

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[6] Garber, R. J., and Quesenberry, K. S.—"Natural Crossing in Oats at Morgantown, W. Va." *Jour. Amer. Soc. Agron.* Vol. 19, No. 2, p. 194. February, 1927.

[7] Montgomery, E. G.—"Oats." *Nebr. Agr. Expt. Sta. Bul. 113.* 1910.

[8] Trowbridge, P. F.—"Experiment Station Progress." *N. Dak. Agr. Expt. Sta. Bul. 194*, p. 12. 1926.

[9] Grantham, A. E.—"Tillering as a Factor in Determining the Desirable Qualities of Winter Wheats." *Jour. Amer. Soc. Agron.* Vol. 4, p. 81. 1912.

In general, workers agree that so far as any one variety is concerned, the extent of tillering is affected by the moisture, fertility and the physical condition of the soil, temperature, and sunlight. Smith[10] reviews the literature on tillering and states that experimenters are not fully agreed as to the importance of the tillering ability of cereal plants. Some have considered scant tillering as an advantage as the secondary heads sometimes produced but little grain, and that, of light weight and poor quality. Others have found a positive correlation between tillering and yield and conclude that cereal varieties of high tillering ability are likely to be good yielders. Smith made 8000 observations on 64 varieties of spring wheat, oats, and barley at Dickinson, North Dakota, and found no uniformly close relation between the extent of tillering and yield, either in a comparison of varieties within a crop, or in a comparison of groups of crops.

Durum wheat tillered less than varieties of common wheat of the Blue stem group. Oats tillered least, while barley slightly exceeded wheat. In seasons of abundant rainfall tillering enabled the plant to respond to the favorable moisture conditions and, as a result, to produce larger yields.

512. Lodging of Cereals. Lodging is the bending over or falling down of the plants. Various factors seem to influence the degree of lodging which will take place. The influence of most of these factors is expressed in the formation of weak, etiolated stems, due to a rank dense growth.

Plants may recover from lodging when the plant is still in the green and growing condition at the time of lodging. This recovery is due to growth at the node. One side of the node grows faster than the other and makes a sort of elbow joint, thus raising the end of the stem.

Garber and Olson[11] report that the early and medium oat strains examined showed a distinct correlation between the thickness of the lignified cell walls and resistance to lodging. Certain varieties are notably resistant to lodging while other varieties are equally susceptible.

Wisconsin[12] gives data showing the effect of the rate of seeding and the season on the tendency of oats to lodge.

[10] Smith, Ralph W.—"The Tillering of Grain as Related to Yield and Rainfall." *Jour. Amer. Soc. Agron.* Vol. 17, No. 11, pp. 717-724. Nov., 1925.

[11] Garber, R. J., and Olson, P. J.—"A Study of the Relation of Some Morphological Characters to Lodging in Cereals." *Jour. Amer. Soc. Agron.* Vol. 11, No. 5, p. 186, May, 1919.

[12] Leith, B. D., and Delwiche, E. J.—"Wisconsin Oats." *Wis. Agr. Expt. Sta. Bul. 340.* 1922.

512a. Rate of seeding and the season as influencing lodging. Wisconsin.

RATE OF SEEDING	1917 AND 1918	1919	1920	1921
1 bu.	No. lodging	0	0	0
2 bu.	No. lodging	33%	0	0
3 bu.	No: lodging	100%	50%	0
4 bu.	No. lodging			60%

Stuch[13] found that an optimum supply of nitrogen resulted in strongly developed culms which favored strength of straw, whereas heavy applications of nitrogen produced thin cell walls and lax tissues and reduced culm strength. Heavy phosphorus applications favored strength of straw in all tests, the cell walls being thicker.

513. Structure of the Seed. In the seed, the outer layer, the hull or testa, includes the thin pericarp and the aleurone layer. In barley this pericarp is united and grown together with the lemma and palea. The embryo or germ is near one end and on the side of the kernel next to the lemma. Reserve food is stored within the endosperm, most of which is starch with very small protein bodies distributed throughout the seed among the starch grains. The protein occurs especially in the outer portion of the endosperm. When these small protein bodies fill the spaces between the starch grains completely, the endosperm becomes translucent or horny and the kernel is said to be flinty. If the intervals are not closely filled, air spaces remain and the endosperm becomes opaque and the kernel is mealy or floury; floury kernels giving rise to the so-called yellow berry condition in wheat.

514. Weight per Bushel and Feeding Value of Cereals. In determining the production per acre the bushel is usually used as the unit. In giving yields in bushels per acre we are often inclined to forget that the feeding value of these bushels is not equal. The United States Department of Agriculture[14] reports the weight per bushel, per cent of hull and comparative nutritive value and nutritive ratio of various cereal crops in Table *514a.*

Henry and Morrison[15] report the total digestible nutrients for the different cereals in per cent as follows: rye, 81.0; corn, 85.7; wheat, 80.1; hull-less barley, 80.4; grain sorghum, 80.0; common barley, 79.4; proso millet, 77.5; emmer, 76.5; oats, 70.4.

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[13] Stuch, P.—"Beiträge zur Untersuchung der Halmfestigkeit bei Getreidearten unter dem Einfluss der Düngung und sonstiger Einflusse." *Ztschr. Pflanzenernähr. u. Düngung. Teil A*, Vol. 7, No. 5-6, pp. 228-289. 1926.

[14] Chamberlain, Joseph S.—"The Feeding Value of Cereals as Calculated from Chemical Analyses." *U. S. Dept. Agr. Bur. Chem. Bul. 120.* 1909.

[15] Henry, W. A., and Morrison, F. B.—*Feed and Feeding*, pp. 728-729. 18th Edition. Henry-Morrison Co. Madison, Wis. 1923.

514a. Comparison of the small grains for feeding.

Crop	Weight per Bu.	Per Cent Hull	Comparative Nutritive Value	Nutritive Ratio
Wheat	60	0	89.00	6.5
Rye	54	0	88.96	6.9
Oats	32	30	73.01	5.8
Barley (common)	48	15	84.92	8.0
Barley (hulless)	60	0	....	6.7
Corn	56	0	95.10	12.3
Emmer	30	40	70.06	6.0
Grain sorghum	56	0	87.88	10.5
Millet (Proso)	50	—	78.73	11.5

The average acre yields of the common cereals for the United States (for the period 1914 to 1920) was: corn, 27 bu.; oats, 33.4 bu.; wheat, 14.6 bu.; barley, 25.4 bu.; rye, 14.8 bu. Eliminating the hulls, the acre yields in pounds were: corn, 1512; oats, 748.4; wheat, 876; barley, 1039.9; and rye, 799.2.

515. Growing Grains in Combination. Considerable acreages of mixed grains (succotash) are grown in some localities. In Ontario, Canada, a study of the acreage devoted to different crops in 1921 indicated that oats led, with fall wheat second, mixed grains third, barley fourth, and corn fifth. Over 600,000 acres were used for growing mixed grains. The average yield from 7 different mixtures compared through a period of 6 years is reported by Zavitz from the Ontario station,[16] as shown in Table *515a.*

515a. Yield of grain mixtures in pounds of grain and tons of straw; six-year average. Ontario.

Varieties of Grain Grown in Mixtures	Tons Straw		Pounds Grain	
	Grown Separately	Grown in Mixtures	Grown Separately	Grown in Mixtures
Barley and oats	1.56	1.74	1935	2261
Barley, peas, and oats	1.47	1.67	1489	2101
Barley, wheat, and oats	1.47	1.72	1683	2067
Peas and oats	1.52	1.77	1873	1988
Barley, peas, wheat, and oats	1.43	1.71	1682	1955
Wheat and oats	1.52	1.68	1624	1921
Peas, wheat, and oats	1.44	1.73	1642	1860
Barley and peas	1.33	1.56	1740	1760
Barley, peas, and wheat	1.32	1.57	1553	1665
Wheat and barley	1.33	1.41	1491	1558
Peas and wheat	1.29	1.37	1429	1322

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[16] Zavitz, C. A.—"Grains Grown in Combination for Grain Production." *Jour. Amer. Soc. Agron.* Vol. 14, No. 6, p. 226. Sept., 1922.

Zavitz reports that the best mixture of barley and oats is 48 pounds of barley and 34 pounds of oats to the acre. It is recommended that the best yielding, adapted varieties which mature at the same time be selected for mixing. Zavitz found that there was no advantage in growing various varieties of a particular grain in a combination. It is stated that in general under Ontario conditions oats has the greatest influence on the productiveness of a mixture, then barley, peas, and wheat.

Various combinations of grain were compared at the Belle Fourche station in South Dakota.[17] The results are given as an average for 3 years in Table *515b*.

515b. Yields of small grain mixtures. South Dakota.

Crop Seeded	Yield, lbs.
Barley alone	1818
Oats alone	1816
Wheat alone	1705
Barley and oats	1922
Barley and wheat	1719
Oats and wheat	1769
Barley, wheat, and oats	1774

Twenty-two mixtures of grain were compared with the various grains grown alone at the Montana station.[18] The ten highest yields were made by the following crops or mixtures in the order named (1) barley alone, (2) wheat alone, (3) barley, ½ bushel, oats, 1½ bushels, (4) wheat, ½ bushel, barley 1½ bushels, (5) oats alone. All other combinations yielded lower than oats.

The Illinois station [19] reports yields from northern and central Illinois, secured from a bushel of 60-day oats and a bushel of the Manchuria type barley per acre. These results are compared with yields secured from these grains grown alone and seeded at the usual rates.

Small grain mixtures and cereal-flax mixtures have been tried at Wooster, Ohio [20] with average yields for 3 years available as shown in Table *515d*.

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[17] Martin, John H.—"Experiments with Cereals on the Belle Fourche Experiment Farm." *U. S. Dept. Agr. Dept. Bul. 1039*. 1922.

[18] Cardon, P. V.—"Grain Mixtures and Root Crops under Irrigation." *Mont. Agr. Expt. Sta. Bul. 143*. 1921.

[19] Dungan, G. H., Stark, R. W., and Burlison, W. L.—"Varieties of Barley for Illinois." *Ill. Agr. Expt. Sta. Bul. 297*. 1927.

[20] Williams, C. G.—"Forty-fourth Annual Report of the Ohio Agricultural Experiment Station for the Year Ended June 30, 1925." *Ohio Agr. Expt. Sta. Bul. 392*, p. 28. 1926.

515c. Comparative tests of barley and oats grown alone and as companion crops; pounds per acre. Illinois.

Field		1915	1924	1925	1926	Average
DeKalb (Northern)	Barley alone	....	....	3,240	2,838	3,039
	Oats alone	....	....	2,134	1,875	2,005
	Cereal mixture	....	....	2,684	2,355	2,520
Urbana (Central)	Barley alone	2,650	2,480	1,410	2,511	2,263
	Oats alone	2,483	2,354	1,275	2,224	2,084
	Cereal mixture	2,793	2,543	1,368	2,415	2,280

515d. Yields of small grain mixtures and of mixtures with flax. Ohio.

Seeding Rate per Acre	Yield per Acre		Grain			
	Grain Lbs.	Straw Lbs.	Wheat %	Barley %	Flax %	Oats %
Oderbrucker barley, 2 bu.	1,482	2,352	....	100.0	....	....
Oderbrucker barley, 1 bu. Fulghum oats, 1 bu.	1,607	2,560	....	56.37	....	43.63
Oderbrucker barley, 1 bu. Marquis spring wheat, 1 bu...	1,342	2,358	42.65	57.35	....	....
Fulghum oats, 2 bu.	2,150	2,663	....	....	....	100.0
Marquis spring wheat, 2 bu...	1,340	2,373	100.0	....	....	....
Fulghum oats, 1 bu. Flax, ¼ bushel	1,720	2,800	....	....	10.18	89.82
Oderbrucker barley, 1 bu. Flax, ¼ bushel	1,498	2,478	....	91.21	8.79	....
Marquis spring wheat, 1 bu Flax, ¼ bushel	1,081	2,222	84.74	....	15.26	....
Marquis wheat,[a] 1 bu. Fulghum oats, 1 bu.	1,057	1,632	59.97	....	....	40.03
Flax, ½ bushel	950	2,710	....	....	100.0	....

[a] Two years only, 1923 omitted.

516. Flax and Small Grain Mixtures. Wheat and flax have been grown together at several stations in the northern part of the United States. In South Dakota, as a 2-year average the highest yields of grain were obtained from a seeding of 15 pounds of flax and 75 pounds of wheat per acre.[21] The yield of the combination was 1446 pounds of grain; wheat alone, 1351 pounds; flax alone, 904 pounds.

McKee reports [22] (Montana) that wheat and flax mixed in proper proportions and grown under irrigation produced total yields that were significantly larger than those obtained from either crop grown alone. He found also that a mixture of 14 pounds of flax and 30 pounds of wheat or 14 pounds of flax and 45 pounds of wheat was the most economical mixture. Yields from these mixtures averaged 25 per cent higher than the average of wheat and of flax sown alone. The average return was $13.50 per acre more for the mixtures than was obtained from wheat alone. McKee reported that apparently the flax-wheat mixture was not adapted to growing under dry land conditions.

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[21] Martin, John H.—"Experiments with Cereals on the Belle Fourche Experiment Farm." *U. S. Dept. Agr. Dept. Bul. 1039*, p. 64. 1922.

[22] McKee, Clyde—"Flax Wheat Mixtures under Irrigation." *Mont. Agr. Expt. Sta. Bul. 202.* 1927.

Arny [23] reports the acre yields of wheat and flax grown in mixtures and alone in Table *516a*.

516a. Yields of flax-wheat mixtures. Minnesota.

CROP	RATE OF SEEDING PER ACRE	PROPORTION OF EACH CROP IN MIXTURES SOWN	PROPORTION OF EACH CROP IN MIXTURES HARVESTED	3-YEAR AVERAGE YIELDS PER ACRE	AVERAGE YIELDS PER ACRE WITH YIELDS OF CROPS GROWN ALONE AS 100
3-Yr. Av. 1917-1919	Pounds	Per Cent	Per Cent	Bushels	Per Cent
Marquis wheat	45.0	62.50	91.27	31.21	....
Primost flax	28.0	37.50	8.73	2.68	105.1
Marquis wheat	15.0	26.32	75.34	18.71	....
Primost flax	42.0	73.68	24.66	6.12	110.0
Marquis wheat alone..	90.0	100.00	100.00	41.98	100.0
Primost flax alone....	42.0	100.00	100.00	9.14	100.0
Marquis wheat	45.0	62.50	76.55	15.71	....
N. D. Resistant flax .	28.0	37.50	23.45	5.38	107.4
Marquis wheat	15.0	26.32	40.86	6.47	....
N. D. Resistant flax .	42.0	73.68	59.14	19.84	102.5

SMALL GRAIN IMPROVEMENT

The means of improving cereals in the past have been the introduction of better types and varieties from other sections and the isolation of superior pure lines, while at the present time considerable work is being done in hybridization or crossing. (509 and 510.)

517. Introduction of New Strains of Small Grain. In the older grain growing areas of the world, strains have developed, apparently well suited to the particular soil and climatic conditions constituting the environment. One of the chief means of improving our own small grain in this country has been the introduction of these strains, trying them out in comparison with the varieties already being grown in the different parts of the country, and in this way finding many varieties markedly superior to varieties previously available.

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[23] Arny, A. C.—"Wheat and Flax as Combination Crops." *Minn. Agr. Expt. Sta. Bul. 206.* 1924.

One of the most important of the earlier wheat introductions was that of Turkey or Crimean. This hard red wheat, with high quality for milling purposes, coming originally from Crimea in southern Russia, has extended the hard red winter wheat belt both north and west due to its winter hardiness and its drouth-resistant quality. The introduction of the Mediterranean, Fife, Kubanka, and Kharkov wheats has been among some of the more important wheat introductions into this country.

FIG. 100.—The late Frank E. Meyer, agricultural explorer, United States Department of Agriculture, returning from a successful trip into the high mountains of central China. Many of the most valuable varieties of field crops have been introduced from other parts of the world by our agricultural explorers.

Some of the more important oat introductions were the Swedish Select by Carleton from Russia, the Kherson introduced from Kherson, Russia, the 60-day oat, very similar, from the same general section, the North Finnish Black from Finland, the Algerian Red from Algeria, and the Clydesdale from Scotland.

The more prominent barley introductions are Manchuria from Germany, coming originally from the mountainous regions of Manchuria, Hanna from Moravia, Smyrna from Asia Minor, and the Beldi and Pelki from Algeria at the edge of the Sahara desert. Each of these introductions, especially those brought in by the United States Department of Agriculture, was given an extensive testing in all parts of the country. In many cases these introductions have provided excellent material for selection work in this country since very few, if any, of these varieties appear to have originated from pure lines.

518. Mass Selection. Mass selection was one of the first methods used as a means of improving small grains. In employing this method a number of the best types or best plants were picked, threshed, and the seed planted together for increases. Several superior varieties were developed by mass selection before better methods had been determined upon.

519. Pure Line Selection. The greatest number of varieties or strains of the small grains have been developed by pure-line selection. A pure line is a selection from a single plant, the progeny of which have not been pollinated with foreign pollen. Most of the varieties introduced into this country were a mixture of a large number of different types of strains. The method of breeding usually followed consists of selecting outstanding individual plants, planting the seed from these in rows in the field in comparison with other plants so selected, and the selection of the best of these rows for planting in larger plots the next year. The testing is continued through a series of years before the very best of these are further increased and planted in comparison with varieties already available. In this way such varieties as Iowa 103 (Albion), Iowa 105 (Richland), Iogren, Iogold, Kanota, and Gopher oats; Minturki, Minhardi, Kanred, Illred, Michikoff, and Purkoff wheats, have been developed.

520. Hybridization of Small Grain. In recent years much attention has been given to the hybridizing of small grains in order to secure new combinations of desirable characters such as disease resistance, resistance to lodging or to winter killing, and yielding ability. Some of the outstanding small grain varieties which are the result of hybridization are Fulcaster, Marquis, and Hybrid 128 wheats and Markton oats. Hybridization is not so easily accomplished in the small grains—wheat, oats, and barley—as in corn. The operation of crossing consists essentially of tearing the lemma and palea of the flower apart with forceps, taking the stamens bodily out of the flower before they are ripe and introducing pollen taken from a ripened flower of the plant selected for the male parent. After pollination of the flowers, precautions are sometimes taken to prevent the contamination with stray pollen, by bagging the panicle or spike.

521. Pollination in Rye as Related to Methods of Breeding. While wheat, oats, and barley are self-pollinated, rye is generally cross-pollinated and self-sterile. (510)

Brewbaker[24] found that where single rye heads were bagged the percentage of seed set in 1921 was 1.7 and in 1922 the per cent was 10.6. Some selfed strains were found to be uniformly vigorous year after year while others were uniformly weak. Rye is somewhat similar to timothy and sunflowers in this respect in contrast to the much greater reduction in vigor of corn as a result of inbreeding. Brewbaker states that the results secured justify the conclusion that the method of breeding rye by selection in self-fertilized lines is not only feasible, but the most effective means for improvement.

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[24] Brewbaker, H. E.—"Studies of Self-fertilization in Rye." *Minn. Agr. Expt. Sta. Tech. Bul. 40.* 1926.

522. Grading Small Grain Seed. A great many experiments have been conducted to determine the influence on yield of fanning and grading small grain seed in order to separate out the larger or heavier seed for planting. In Tables *522a*, *522b*, and *522c* groupings have been made so far as possible on the basis of the method used in separating the seed into the different grades or of the method of making the comparison in the field. (334 and 335.)

522a. Grading seed oats; yields in bushels per acre except where per cent is indicated. Summary.

WORK DONE AT	YEAR REPORTED	DURATION YEARS	ORIGINAL SEED	LARGE OR HEAVY	MEDIUM	SMALL OR LIGHT
1. Normal rate of seeding without reference to size and weight						
Nebraska	1912	1	....	48.32	...	43.85
Ontario, Can.	1908	7[a]	....	62.0	54.1	46.6
2. Equal numbers of seed planted; usually hand selected						
Nebraska	1917	5	....	46.1	...	41.0[b]
Nebraska	1912	1	....	100.0[b]	...	93.0
3. Equal weights of seed planted						
Nebraska	1917	5	....	46.1	...	46.1
4. Equal areas planted with same weight of seed						
Nebraska	1917	1	....	100.0	...	84.0
5. Primary oats compared with secondary						
Ohio	1913	5	Primary	100.0[b]	Secondary	94.0[b]
6. Seed planted in competition						
Nebraska	1912	....	....	100.0[b]	...	80.0[b]
7. Fanning mill used; field conditions						
Nebraska	1908	3[a]	65.4	66.1	65.8	64.5
Nebraska						
Kherson	1917	12[a]	54.62	55.45	...	54.71
Am. Banner	1917	4[a]	41.77	39.7	...	43.37
Ohio	1913	4[a]	58.23	58.98	...	56.66
Kansas	1897	8[a]	29.89	30.9	...	27.5
Minnesota	1893	1	....	64.09	...	54.59
Iowa	1912	3	48.5	48.3	49.7	49.0

[a] Seed selection has been continuous in each type of seed.

[b] Yields in per cent.

522b. Grading winter wheat seed; yields in bushels per acre except where per cent is indicated. Summary.

WORK DONE AT	YEAR	DURATION	BUSHELS PER ACRE			
			Original Seed	Large or Heavy	Medium	Small or Light
1. Normal rate of seeding without reference to size or weight						
Nebraska	1917	2	40.2	41.1	...	39.0
Nebraska	1912	1	....	47.17	...	43.81
Tennessee	1903	3	....	28.6	...	23.42
Ontario, Can.	1907	6	....	46.9	...	40.4
2. Equal numbers of seed planted; usually hand selected						
Nebraska	1917	4	....	43.2	...	41.3
England	1902	1	....	10.34	...	11.14
England	1903	1	....	19.48	...	19.53
Ohio	1905	1	....	13.21	...	15.68
3. Equal weights of seed planted; usually hand selected						
Nebraska	1917	4	....	43.2	...	43.2
4. Equal areas planted with same weight of seed						
New So. Wales	1903	3	....	100[b]	...	83[b]
5. Fanning mill used; under field conditions						
Ohio	1897	4[a]	13.37	14.0	...	13.74
Ohio	1901	9[a]	16.33	17.06	...	16.21
Ohio	1916	8[a]	31.48	30.82	...	29.98
Utah	1893	4	16.42	18.72	16.6	18.72
Indiana	1891	3	....	30.54	...	27.94
Kansas	1896	4	28.97	29.15	...	27.16
New So. Wales	1901	1	....	9.7	...	7.5
Nebraska	1905	4	....	24.5	...	23.7
Nebraska	1908	8[a]	30.00	30.2	...	29.0
Nebraska	1917	12[a]	33.5	33.9	...	33.0

[a] Seed selection has been continuous in each type of seed.

[b] Yields in per cent.

522c. Grading spring wheat, barley, and rye; yields in bushels per acre except where per cent is indicated. Summary.

Work Done At	Year	Duration	Bushels per Acre			
			Original Seed	Large or Heavy	Medium	Small or Light
Spring Wheat						
1. Normal rate of seeding regardless of size of seed						
Nebraska	1917	2	15.4	18.3	...	14.2
Ontario	1907	8	...	21.7	...	18.0
2. Equal numbers of seed planted						
Nebraska	1917	2	...	14.1	...	12.7
3. Equal weights of seed planted						
Nebraska	1917	2	...	14.1	...	13.9
4. Equal areas planted with the same weight of seed						
North Dakota	1901	4	...	100[a]	...	90[a]
Nebraska	1917	1	...	100[a]	...	64[a]
Barley						
Tennessee	1901	1	...	36.3	...	28.7
Ontario, Can.	1907	6	...	53.8	...	50.4
Germany	1906	1	...	32.1	...	36.4
Rye						
Germany	1895	4	....	26.8	26.3	25.6
Germany	1895	7	....	37.8	38.8	38.5

[a] Yields in per cent.

523. Winter Killing. Salmon[25] gives 4 major divisions of causes for winter killing. These are: heaving, smothering, physiological drouth, and the direct effect of low temperature.

Heaving. In heaving, the plants are lifted from the soil and the roots broken and exposed to the air by the process of alternate freezing and thawing. The soil freezes down rather deeply, expanding as it does this. Thawing, then, starts at the top and the soil releases its hold on the roots of the plants and settles as the ice melts out of it. In subsequent cold periods the soil starts freezing at the surface and expands as it freezes downward, thus pulling on the roots which are held by the frozen layer of soil below the thawed layer. Poorly drained soils are especially liable to heaving, but heaving may occur also on fairly well drained soils. Heavy soils are reported as heaving worse than lighter soils. In many sections of the country most of the loss in seedings of winter grain is the result of heaving.

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[25] Salmon, S. C.—"Why Cereals Winterkill." *Jour. Amer. Soc. Agron.* Vol. 9, No. 8, pp. 354-359. Nov., 1917.

Smothering. Smothering is believed to be the cause of winter killing when an ice sheet forms on the surface of the soil. Respiration cannot go on unless oxygen is present. This layer of ice prevents the entrance of oxygen.

Physiological drouth. Physiological drouth is the condition resulting when a plant cannot get water from the soil. A frozen soil may be physiologically dry. Salmon presents evidence to show that the evaporation of moisture in excess of the plant's ability to get it from the soil will result in the death of the plant. It has also been suggested that the reason for the more hardy types of small grains having narrow leaves is that it lessens evaporation and the danger of physiological drouth. Observations have also shown that grain exposed to the wind is more likely to be killed than that in protected places.

The direct effect of low temperatures. This injury is a mechanical injury due to the formation of ice crystals within the plant tissues. Other investigators have attributed this injury to the rapid melting and evaporation of the water before the cell can absorb it, the water having been extracted from the cell by freezing. In this case the rapid thawing would be the harmful condition, not the freezing. In one case, 63.7 per cent of the water was drawn out of the protoplasm by freezing at —13° C.

524. Means of Preventing Winter Killing. The selection of winter hardy varieties is the most certain way of lessening the loss due to winter killing. Klages[26] studied certain physical and physiological properties of winter wheat varieties with reference to their association to winter hardiness. He found that the most hardy varieties of winter wheat have a comparatively small leaf area in autumn; also, that an erect habit of growth was a better indicator of lack of resistance than a recumbent habit of growth was an indicator of hardiness. Hardy varieties of wheat show a much less rapid rate of growth in the field in the autumn than the non-hardy varieties, though the amount of material produced by the several varieties does not stand in direct proportion to the degree of hardiness.

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[26] Klages, K. H.—"Metrical Attributes and the Physiology of Hardy Varieties of Winter Wheat." *Jour. Amer. Soc. Agron.* Vol. 18, No. 7, pp. 561-562. July, 1926.

The Nebraska[27] station has reported that rolling the land in the spring where heaving had taken place did much to reduce the injury to the crop.

A number of stations report the results secured from planting winter grain in furrows and from the use of straw mulches.

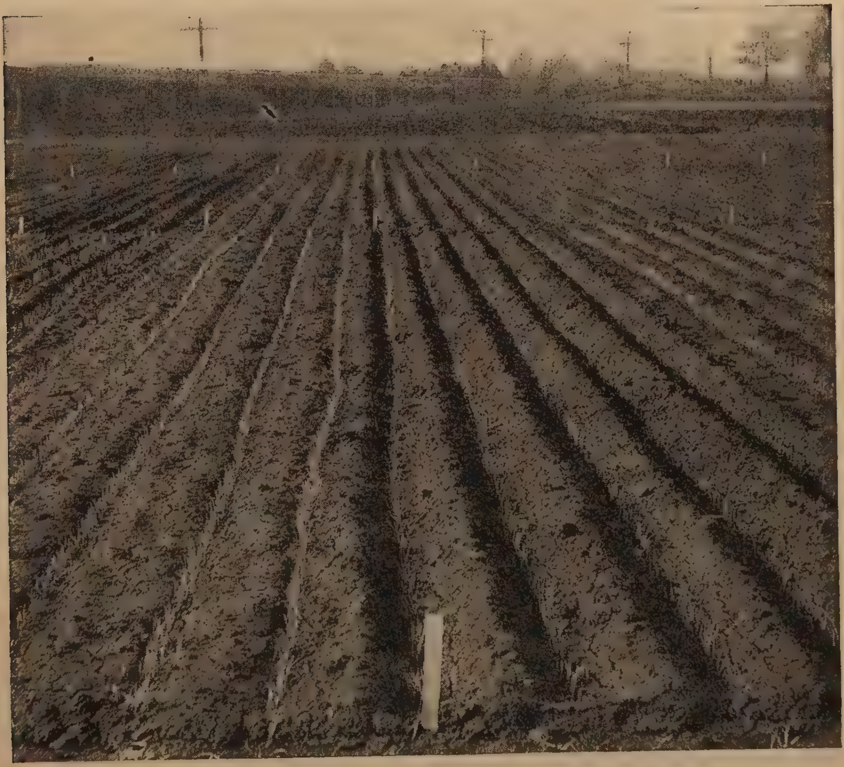

FIG. 101.—Experimental winter wheat at the Iowa Station, furrow and surface planted. *Has the furrow planting of winter wheat been found a desirable method and if so under what conditions and why?*

525. Furrow Planting as Winter Protection. The Georgia station reports[28] that winter oats seeded in deep furrows were not as severely injured as those seeded in a level seedbed.

Winter oats seeded by the deep furrow method in Kansas[29] survived 86.6 per cent in comparison with 7.5 per cent when seeded in the ordinary way.

Salmon reports later experiments in Kansas in which a deep furrow drill was used. This machine opens deep furrows every 12 inches and the grain is planted in the bottom of the furrow between the 2 sharp ridges. The danger of winter killing is lessened as a result of the furrows catching the snow and the weathering of the ridges preventing heaving. Temperature determinations in the drill rows of surface and furrow planted grain, through 5 winters, showed 3, 14, 2, 6, and 3 degrees F. higher in the furrows.

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[27] Kiesselbach, T. A.—"Winter Wheat Investigations." *Nebr. Agr. Expt. Sta. Bul. 31*, p. 127. 1925.

[28] McClelland, C. K.—"Winter Crops." *Ga. Agr. Expt. Sta. Bul. 117*. 1915.

[29] Salmon, S. C.—"Seeding Small Grain in Furrows." *Kans. Agr. Expt. Sta. Tech. Bul. 13*. 1924.

The survival of plants sown in furrows and with an ordinary drill was determined and is reported in Table *525a.*

525a. Per cent survival of five varieties of winter wheat sown with the furrow drill and the surface drill. Kansas.

Variety	Sown with Furrow Drill Per Cent Survival	Sown with Ordinary Drill Per Cent Survival
Kanred	71.4	37.1
Improved Turkey	61.6	20.6
Turkey	81.1	9.7
Kharkov	68.2	10.5
Blackhull	66.2	2.3

At Manhattan[30] the furrow method of seeding for 10 years averaged 27.3 bushels and ordinary planting 27.1 bushels per acre, while at the Fort Hayes station (Kansas) the furrow seeding for 4 years yielded 23.4 and the ordinary method 22.2 bushels per acre.

May and McKee[31] report yields of wheat as a 4-year average where the furrow drill was used with no straw mulch as 27.6 bushels in comparison with the ordinary drill which yielded 22.0 bushels. Where a straw mulch was used, the furrow drill yielded 26.3 bushels and the ordinary drill 23.4 bushels per acre.

Quayle and Nelson[32] report seeding wheat early and late in Wyoming with both the common drill and the furrow drill. The 4-year average yields were: common drill, early seeding, 8.8 bushels; the furrow drill, early seeding, 18.4 bushels; common drill, late seeding, 13.5 bushels; the furrow drill, late seeding, 18.7 bushels.

526. Straw Mulch on Winter Wheat. Ohio[33] reports the effect of mulching the wheat with straw in the following table.

South Dakota[34] reports 12.21 bushels of wheat as a 5-year average yield where 6 tons of rotten manure was used as a mulch

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[30] *Ibid.*, pp. 29 and 36.

[31] May, Ralph W., and McKee, Clyde—"Furrow Drill for Sowing Winter Wheat in Central Montana." *Mont. Agr. Expt. Sta. Bul. 177.* 1925.

[32] Quayle, W. L., and Nelson, A. L.—"A Better Method for Winter Wheat Production." *Wyo. Agr. Expt. Sta. Bul. 151.* 1927.

[33] Williams, C. G.—"Forty-first Annual Report of the Ohio Agricultural Experiment Station." *Ohio Agr. Expt. Sta. Bul. 362.* 1922.

[34] Evans, Arthur T., and Janssen, George—"Winter Wheat in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 200.* 1922.

	5 Year Average Yield of Wheat	Yield of Clover Following
No mulch	35.53 bu.	6,089 pounds
One ton straw per acre	36.76	5,695
One and one-half tons straw per acre	35.47	5,646
Two tons per acre	34.09	5,520

in comparison with 9.09 bushels where no mulch was used. A 2-ton straw mulch was better than a 3-ton mulch at the Highmore station. In other tests a 3-ton mulch prevented winter killing when that not mulched completely killed. In 1917, both mulched and unmulched plots were killed.

At Dickinson, North Dakota,[35] where wheat was grown on corn land with the stalks remaining the yield was 13.5 bushels while on clean cultivated land the yield was 4.7 bushels.

Hume *et al.*[36] report work at Eureka, South Dakota, in which a mulch of 3 tons of straw resulted in perfect survival while unmulched plots were totally killed.

Evans *et al.*[37] compared a 2- and 3-ton rate of mulching in which the 2-ton mulching was superior at each of 5 rates of seeding, with differences of from 1 to 6 bushels per acre.

Sears and DeTurk [38] report that at the Illinois station increases are obtained in exceptional years. During the period from 1917 to 1924 2 years have been profitable for straw mulching.

May and McKee [39] found that in central Montana straw mulching did not consistently decrease or increase the stand in the spring. They experienced difficulty from blowing.

Wheat mulched at the Iowa Station [40] at the rates of 1 and 2 tons per acre in the fall of 1927 came through the winter with good stands, while wheat seeded under the same conditions and not mulched winter killed almost entirely. In general, a greater survival resulted from the use of the 2-ton than for the 1-ton mulch. Mulch applied immediately after seeding did not blow and pile as badly as that applied 30 days later.

When different varieties were seeded at intervals through the late

[35] Clark, J. Allen—"Cereal Experiments at Dickinson, N. Dak." *U. S. Dept. Agr. Dept. Bul. 35.* 1914.

[36] Hume, A. N., Champlin, M., and Morrison, J. D.—"Winter Grains in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 161.* 1915.

[37] Evans, A. T., and Janssen, G.—"Winter Wheat in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 200.* 1922.

[38] Sears, O. H., and DeTurk, E. E.—"Test Methods of Saving Fertility in Straw." *Ill. Agr. Expt. Sta. Ann. Rpt. 37*, pp. 57-58. 1923-24.

[39] May, R. W., and McKee, C.—"Furrow Drill of Winter Wheat in Central Montana." *Mont. Agr. Expt. Sta. Bul. 177.* 1925.

[40] Bower, C. W.—"Winter Killing in Winter Wheat." Unpublished Thesis, Library, Iowa State College. 1928.

fall, with the earliest seeding on October 8, the greatest amount of winter-kill resulted from a seeding which gave fall emergence but no great amount of fall growth. The November 22 seeding gave more survival than any other seeding date, except for Minturki and Mavelous sown Oct. 8. Iobred and Red Cross were rather inferior for the earlier seedings but were superior for the November 7 and 22 seedings. It is suggested that when for some reason seeding has been delayed until the middle of October, better results will probably be secured by delaying the seeding until the middle of November.

Harvesting Small Grain

527. Cutting. By far the larger part of the small grain acreage is cut with binders, with smaller amounts cut with headers and with combine-harvesters. In the grain growing regions binders and headers are often used on the same farm, the binders being used before the crop is ripe enough to cut with the header. In the same way binders and combines are used on the same farms.

Fig. 102.—An Iowa farmer who lived to see one man with a combine-harvester cut and thresh as much grain in one day as would have required 90 men to get the same results with the equipment available to him when he used the cradle on the same field 62 years before.

528. Improvements in Harvesting Machinery. The hand sickle is still used in some parts of the world to harvest grains, while the cradle is still used in some sections of the United States. In general, however, these pioneer methods have long been abandoned. Starting with the sickle, the scythe was an improvement over this, then the cradle, then the reaper, the reaper with bunching attachments, the binder, the header, and finally the combine-harvester. In some sections binders are used which have attachments for shocking the grain as it is cut. The use of the combine, until in very recent years, was confined to rather limited areas of the West where the climate and the varieties grown were such that the grain could be left standing in the field for a considerable time after ripening without deterioration. However, it would appear from recent developments that the sphere of usefulness of the combine is rapdily enlarging.

Something of the progress made in developing more efficient methods of harvesting small grain can be judged by a comparison of the number of the acres harvested per day. Bond[41] states that in the days of hand reaping each man was followed by 1 woman to gather the grain and 1 man to bind the sheaf. The 3 could cut and tie about 1½ acres of winter wheat or 2 acres of spring grain in a day. Generally the raking was done by a boy, 1 to each 2 scythes. The mechanical reaper which came out about 1850 and left the grain in swaths enabled 1 man with two horses to operate the machine, to perform the work of about 6 scythe men. With the addition of a sheafing attachment to the reaper the women who formerly gathered the grain were displaced. The self binder introduced about 1879 enabled 1 man to cut and tie 6 to 10 acres a day, thus displacing from 12 to 20 men.

The scything and binding in New York was perhaps somewhat more rapid than is reported for England. Delafield[42] states that in 1850 in New York the cost of cradling, binding, and shocking was 70 cents per acre on a 20-bushel yield.

An average cradler in Iowa in 1865 cut 2 acres of grain per day and he was followed by a second man who gathered and bound the grain into bundles. These 2 men could flail out the grain from an acre in a day,—3 days' work for 1 man to cut and thresh an acre of grain. In 1927 one of these scythe hands of 1865, on the very land where he had scythed, saw a man, single handed, by means of a combine and tractor, cut and thresh 30 acres of grain in a day, the work of 90 men in 1865.

529. Effect of Width of Cut of Binder or Combine on Acres Cut per Day. A summary of 235 reports of the acres cut by binders with different cutter bar widths is reported by the United States Department of Agriculture.[43]

529a. Width of binder and acres harvested per day.

WIDTH OF CUT	NO. OF HORSES	ACRES CUT	ACRES CUT PER FOOT OF CUTTER BAR
6-foot	3	10.9	1.82
6-foot	4	12.1	2.02
7-foot	3	12.5	1.79
7-foot	4	15.1	2.16
8-foot	4	17.0	2.13

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[41] Bond, J. R.—"August on the Farm." *Jour. Min. Agr.* [Gt. Brit.] Vol. 32, No. 5, pp. 463-464. Aug., 1925.

[42] Delafield, John—"A General View and Agricultural Survey of the County of Seneca." *N. Y. State Agr. Soc. Trans.* Vol. 10, p. 550. 1850.

[43] Yerkes, Arnold P., and Church, L. M.—"Cost of Harvesting Wheat by Different Methods." *U. S. Dept. Agr. Dept. Bul.* 627. 1918.

In cutting grain 2.2 pounds of twine are required to bind 1 acre of average grain. In wheat yielding 15, 20, 26, and 37 bushels, a man can shock 12½, 12, 8¾, and 7½ acres per day, respectively.

530. The Effect of Early Harvest on the Filling of the Grain. Davenport and Fraser[44] harvested wheat in the watery, milk, dough and ripening stages. They report that allowing the grain to cure on the straw resulted in an increase in weight of grain and that this was more pronounced when cured in the shade than in the sun. The grain of wheat harvested at the fully ripe stage showed no increase in weight during the curing process.

Harlan and Pope[45] found that when kernels of barley were kept moist on the culm after harvest there was a further development in both the endosperm and embryo during a period of 8 days.

Olson[46] found that there was a continuous increase in the weight of grain until the moisture content of the grain had been reduced to 40 per cent or less. He states that there apparently is no scientific foundation for the belief that grain will fill after cutting.

Woodman and Engledon[47] state that the ripening process is merely desiccation and that no fresh material enters the kernel during this period.

Arny and Sun[48] report a reduction in yield and in weight per bushel in harvesting both wheat and oats before they are mature. They also found that the weight of 1000 kernels of both wheat and oats, cut at various stages of maturity, weighed as much when dried quickly in an oven as when dried slowly in the shock. They conclude from this data that following harvest there is no significant transfer of materials from straw to grain during the curing process.

531. Maturity at Harvest as Affecting Yield. Kansas[49] reported that oats harvested in the soft dough stage yielded 32.6 bushels, in the hard dough stage 33.0 bushels, and at the fully ripe stage 33.2 bushels per acre.

Kiesselbach and Lyness[50] harvested oats 6 days before they were ripe, 2 days before they were ripe, and when fully ripe. The average yields for these stages were 51.1 bushels, 57.5 bushels, and 57.0 bushels per acre, respectively. The weights per bushel were 27.3, 29.7, and 30.1 pounds, respectively, as a 3-year average.

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[44] Davenport, E., and Fraser, W. J.—"Experiments with Wheat." *Ill. Agr. Expt. Sta. Bul. 41*, 1896.

[45] Harlan, H. V., and Pope, M. N.—"Development in Immature Barley Kernels Removed from the Plant." *Jour. Agr. Res.* Vol. 27, p. 678. 1926.

[46] Olson, G. E.—"A Study of the Factors Affecting the Nitrogen Content of Wheat and of the Changes that Occur during the Development of Wheat." *Jour. Agr. Res.* Vol. 24, p. 953. 1923.

[47] Woodman, H. E., and Engledon, F. L.—"A Chemical Study of the Development of the Wheat Grain." *Jour. Agr. Sci.* (London). Vol. 14, p. 463. 1924.

[48] Arny, A. C., and Sun, C. P.—"Time of Cutting Wheat and Oats in Relation to Yield and Composition." *Jour. Am. Soc. Agr.* Vol. 19, p. 410. 1927.

[49] Georgeson, C. C., Cottrell, H. M., and Shelton, Wm.—"Experiments with Oats." *Kan. Agr. Expt. Sta. Bul. 13.* 1890.

[50] Kiesselbach, T. A., and Lyness W. E.—"Spring Small Grains." *Nebr. Agr. Expt. Sta. Bul. 201.* 1924.

Cardon [51] reports as an average of 4 years, wheat harvested in the green dough stage produced 10.9 bushels; the hard dough stage, 14.9 bushels; the fully ripe stage, 14.1 bushels; and the over ripe stage, 13.4 bushels.

Zavitz [52] (Ontario, Canada) reports an experiment in cutting wheat in which 2 varieties of winter wheat were each cut on 5 different dates, allowing 1 week between cuttings, the middle cutting being made at about the normal time and the fifth cutting at the "dead ripe" stage. The seed planted in each year following the first was from the corresponding stage of cutting of the previous year's crop. The average yield through a 29-year period for these 5 stages of cutting was 47.9; 57.0; 60.0; 60.0, and 58.8 bushels per acre, respectively.

Kiesselbach [53] found the maximum weight of dry matter 2 days before the dead ripe stage when the grain contained 29.9 per cent moisture. Two days previous to this the moisture was 38.4 per cent. He also reports a considerable increase in yield of wheat as the wheat goes from the early to the late dough and ripe stages.

532. The Effect of Delayed Harvest on Yield. The increased use of the small combine harvester throughout the corn belt has suggested the desirability of determining the effect of delayed harvest on yield under these conditions.

Burnett and Bakke [54] made semi-weekly cuttings of different varieties of wheat, oats, and barley, beginning on the normal binder harvest date and continuing until the loss of grain became excessive. The cut grain was handled in such a way as to prevent the loss of kernels in the harvesting process. The air dry yield and moisture content was determined for each variety at each date of harvest. The normal binder harvest date, with the moisture content of the grain, also the date and moisture content when the highest yield was secured, is shown in Table *532a*, for 1927 and 1928. The season of 1927 was considered ideal for combine harvesting while 1928 was very unfavorable.

[51] Cardon, P. V.—"Tillage and Rotation Experiments at Nephi, Utah." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 157.* 1915.

[52] Zavitz, C. A.—"Forty Years' Experiments with Grain Crops." *Ontario Agr. Expt. Sta. Bul. 332.* 1927.

[53] Kiesselbach, T. A.—"Winter Wheat Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 31.* 1925.

[54] Burnett, L. C., and Bakke, A. L.—"The Effect of Delayed Harvest on the Yield of Grain." *Iowa Agr. Expt. Sta.* (unpublished). 1929.

532a. *Date and moisture content of grain at binder harvest and when maximum yield was secured. Iowa.*

VARIETY AND GRAIN	1927				1928			
	NORMAL CUTTING WITH BINDER		FOR HIGHEST YIELD		NORMAL CUTTING WITH BINDER		FOR HIGHEST YIELD	
	Date	Moisture Content	Date	Moisture Content	Date	Moisture Content	Date	Moisture Content
Iobred Wheat	July 11	38.8	July 18	14.8	July 14	34.0	July 16	25.5
Iogold Oats	" 11	28.0	" 21	10.0	" 17	30.0	" 16	33.5
Iowa 105 Oats	" 14	35.4	" 25	10.4	" 15	31.0	" 16	26.5
Iowar Oats	" 19	22.8	" 22	15.6	" 17	35.5	" 18	24.8
Oderbrucker Barley	" 14	35.8	" 21	16.8	" 19	29.5	" 24	18.0
Trebi Barley	......	...	......	...	" 17	32.0	" 14	40.5

The number of days following the normal binder harvest date for the different varieties, during which period the yields secured were at least equal to those on the first harvest date was found to be as follows:

VARIETY	IOBRED WHEAT	IOGOLD OATS	IOWA 105 OATS	IOWAR OATS	ODERBRUCKER	TREBI BARLEY
Days in 1927	21	25	28	5	12	..
Days in 1928	14	13	13	12	7	17

Burnett and Bakke suggest the following considerations as vital in determining the possible duration of the harvest period: (1) soil and other cultural influences; (2) climate, with its effect on the development and maturation of the kernel, also its influence on yield losses, and (3) the crop variety. They suggest the variety as a very important factor.

533. Shocking. Practically all small grain cut with a binder is placed in shocks for curing. If the grain is ripe or in the hard dough stage when cut it may be placed at once in round shocks, where the grain is more or less protected from damage from the rain or dew. If the grain is green or if the bundles contain many weeds, it should be allowed to cure for a few hours before shocking. Grain in this condition is often shocked in what are termed "long shocks" as long shocks allow the sun and air to penetrate much more readily than round ones.

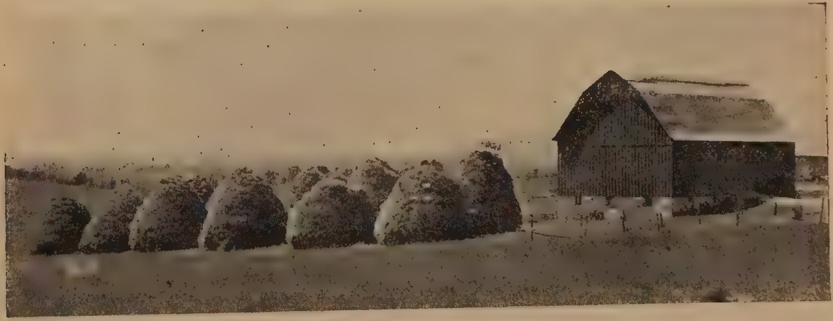

FIG. 103.—Small grain in the stack on an Ohio farm. *What is the cost of stacking small grain as compared with threshing direct from the shock? Under what conditions is stacking advisable?*

534. Stacking Grain. Much wheat cut with a binder in the winter wheat belt is threshed from the shock without stacking at all. Wheat cut with a header is stacked immediately, usually in ricks or long stacks, while for bundle grain, stacks from 12 to 16 feet in diameter are the type usually built. Stacks are usually set about ?

feet apart for convenience in setting the threshing machine and pitching. In stacking bundle grain the stack is started very much the same as the shock of wheat in the center. To this bundles are added in rows round and round the shock, leaning against the shock, each succeeding row becoming flatter than the one preceding it till the outer row lies almost flat, but still overlapping so that none of the heads touch the ground. The second layer of bundles is laid on the outer edge with the butts out. The second layer is lapped on these to hold them in place. It is important in stacking that the center be kept full so that the bundles are all sloping downward and out. Whether the grain is to be stacked or not depends on the local conditions. Grain can be threshed from the shock as soon as it is thoroughly dry. Whether it is best to stack or thresh direct from the shock will depend upon the relative cost of shock and stack threshing and the possibility of getting the grain threshed at the proper time. Some investigations indicate that stack threshing adds about one and one-half cents per bushel to the cost of producing oats. Only a very small per cent of the farmers in the dry portions of the winter wheat belt stack their bundle grain and most grain is shock threshed in the central corn belt with more stacking eastward.

535. Threshing Grain. In 1920, a survey in Kansas[55] showed 877 men who were accustomed to employ threshing outfits to do their work, 168 were owners of machines and did their own threshing and in many cases their neighbors as well, and 68 who did their threshing in coöperation with other farmers owning a machine coöperatively. The number of bushels threshed per day depends directly upon the size of the machine and of the crew. An average day's run, threshing bundles from the shock, was 1076 bushels. In threshing headed wheat from the stack the average was 1450 bushels per day. The average crew for shock threshing was 17 men, 20 horses, and 10 wagons. When threshing stacked bundles the crews were smaller, the average being 10 men, 6.4 horses, and 3.8 wagons. The average crew in threshing headed grain from the stack was 11.3 men, 8.2 horses, and 4.5 wagons.

536. The Combine Harvester. Apparently the combine harvester, formerly found only in dry land areas of the far West and Northwest, is to play an important part in grain production throughout the whole of the Great Plains area and even in the central corn belt.

Lehmann and Blauser[56] state that in Illinois the first combine or harvester was used in the fall of 1924. This number had increased to 64 in 1926. When the combine was used in the harvest of wheat in Illinois, the loss was 5.76 per cent, while the total loss with a binder and ordinary thresher was 8.76 per cent. The use of the combine greatly reduced the loss in harvesting soybeans. They state that it is necessary to delay going into a field with a combine an average of 2 days following each rain in July and August. Therefore, the distribution of rainfall during harvest is a more important influence in harvesting with a combine than the total amount of rainfall during the harvest season. A study of the seasons from 1910 to 1926 indicated that the combine could be used an average of 15 days during the harvest period, while the lowest number of days found suitable for any one year was 11. Standing grain dries out much faster after a heavy rain than shocked grain, but a very light shower which would not stop shock harvesting might delay combining for a number of hours. (528)

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[55] Mohler, J. C.—"Wheat in Kansas." *Kans. State Bd. Agr. [Quart.] Rpt.* Vol. 39, No. 155, pp. 106-108. Sept., 1920.

[56] Lehmann, E. W., and Blauser, I. P.—"Combines in Illinois." *Ill. Agr. Expt. Sta. Circ. 316.* 1927.

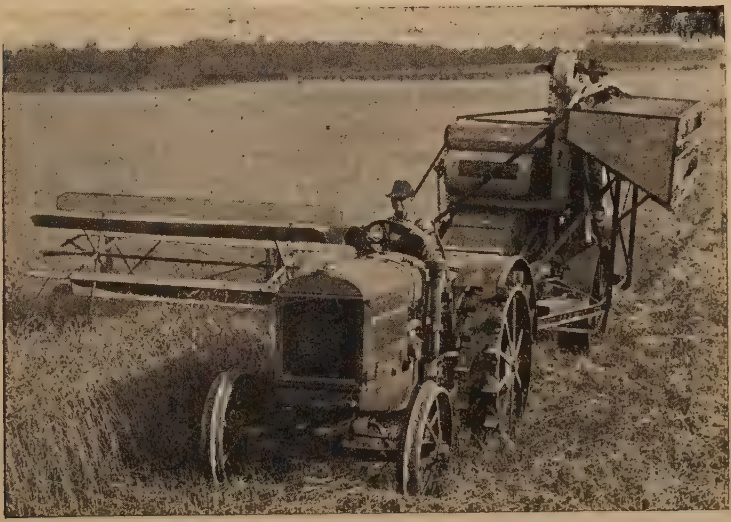

FIG. 104.—The combine harvester at work on an Indiana farm. *What is the cost of harvesting wheat with the combine as compared with binding, shocking and later threshing? Under what condition is it economical to use the combine?*

STUDY QUESTIONS ON CHAPTER XVIII

1. List the characteristics common to all the small grains.
2. Can two varieties of wheat be planted in rows a foot apart and remain practically pure? Why? Rye? Oats? Barley?
3. What determines the number of culms that will be produced by a single wheat seed?

4. What is the cause of lodging in grain? What are the remedies?
5. What is the relation between "yellow berry" and the protein content of wheat? What condition results in "yellow berry"?
6. How many bushels per acre of each of the small grains would be required to give the same total digestible nutrients as a 50 bu. corn crop?
7. Under what conditions is it feasible to increase the production per acre by mixing small grains? Is this generally advised? Why?
8. Outline the methods used in improving small grain. Which method promises the most improvement in the future for each type of grain?
9. Under what conditions are the fall-seeded small grains most likely to be killed? What precautions can be taken which will reduce the danger of winter killing?
10. Trace the development of harvesting machinery and the progress that has been made in the saving of labor. Where is each type of harvester used today?
11. What factors influence the time of cutting small grain? At what stage of maturity would you advise cutting each grain?
12. Would you advise shocking, threshing, or stacking for your locality? Why?

APPLICATION ASSIGNMENTS ON CHAPTER XVIII

1. You are planting oats on a field which is so rich that the small grain usually lodges. What precautions will you take?
2. Your local market pays a good premium for high protein wheat. You have two fields available. One is average in fertility, high and inclined to be dry. The other is low and very rich. Which will you use for wheat? Why?
3. You have but 20 acres of average soil for small grain and wish to secure the highest amount of food value per acre. What crop will you grow? What acre yields of the other small grains would be required to make them equivalent?
4. Your seed oats are of fair quality and free of trash and weed seed. By using the fanning mill you can raise the weight per bushel 4 pounds. Will you fan? Why? Would you advise the general fanning of seed oats? Why?
5. The wheat crop on a portion of your field is unusually good. Will you save your seed from this portion of the field? Why?
6. In spite of the risk of winter killing in your section you intend to plant winter wheat. You must choose between a flat, heavy, moist, clay loam, and a sandy loam on more rolling ground. On which field will you plant wheat? Why? In what other ways can you lessen the danger of winter killing?
7. Your field of wheat has lost practically half of its green color. The kernels are not sufficiently mature but that they can be crushed with the thumb nail. If you do not cut now you will need to wait ten days. What will you do? Why?

8. Your oats are rank in growth and in the soft dough stage. You are afraid that with a heavy wind or rain they will lodge. Will you cut? Why?
9. You operate a grain farm with very little live stock. As an average you have 60 acres of small grain each year, half wheat and the other either oats or barley. You are considering the purchase of a combine. Will you buy one? Why?

CHAPTER XIX

WHEAT AND RYE

WHEAT

For the period 1895 to 1914 the average annual production of wheat for the United States was 641,000,000 bushels and for Russia 593,000,000 bushels. The third most important country was India with 280,000,000 bushels. Argentine produced 113,000,000; Canada, 112,000,000; and Australia, 63,000,000 bushels. Statistics are not available for Russia since 1915, but apparently production in Russia and in the United States increased at about the same rate until very recently. The production of wheat in Canada has increased rapidly, and, in 1920, Canada went into third place. The production in India and Argentine does not seem to be increasing. (Figure 3.)

537. Origin of Wheat. Writers are not in entire accord with regard to the origin of wheat, but all agree that at the dawn of history its cultivation was general in western Asia. Cultivation in China, at least, is very ancient. A ceremony instituted in the 28th century B.C., in which 5 types of grain were seeded each year, includes wheat among the five. The other crops were rice, millet, proso millet, and soybeans. It is a well known fact that the "corn" of the Bible referred to small grain, with certain types of wheat generally grown. Carleton states[1] that wheat is native in Servia, Crimea, the Caucasus, and in Asia Minor. Wheat is not native in America, but the crop was grown in the Virginia colony as early as 1618.

538. Climatic Adaptation of Wheat. Baker[2] states that only barley, potatoes, and certain hay crops are grown under colder conditions than wheat. He also states that no part of the earth is too hot for the production of wheat if the climate is not humid, wheat being an imporant crop in some of the hottest parts of the earth. It is the humidity of the tropics which restricts wheat very largely to the temperate zones. Moist warm atmospheres are the regions where rusts and other diseases of wheat flourish.

Baker also states that wheat has both humid and arid limits. The humid limit varies with the temperature. In southeastern United

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[1] Carleton, Mark Alfred—*The Small Grains*, p. 34. The Macmillan Company, New York. 1919.

[2] Baker, O. E.—"The Potential Supply of Wheat." *Econ. Geog.* Vol. 1, No. 1, pp. 24-27. Mar., 1925.

States very little wheat is grown where the average temperature for the 2 months preceding harvest exceeds 68° F. and where the rainfall exceeds 50 inches annually. In the northeastern part of the United States, where the temperature during these months is a few degrees cooler, 40 inches of rainfall annually practically marks the humid boundary of wheat production. Most of the wheat is grown in regions where the annual rainfall averages less than 30 inches. In general, near the cold limit of wheat production, 40 inches of precipitation approximately marks the limit, while in the warmer sections, 70 inches seems to be the upper limit.

The arid limit of wheat production varies with the temperature also. Wheat is grown in central Washington on a lower annual rainfall than elsewhere in the United States. The arid limit in this section is about 9 inches per year, the rains coming in the winter and spring when the evaporation is small. In central Alberta the crop is usually grown on about 11 inches received in spring and summer. In western Texas, where the summer temperature is 20 degrees higher and with much the same seasonal distribution of rainfall, about 19 inches of precipitation marks the arid limit, while in India approximately 20 inches is the limit.

Summarizing, Baker states that wheat near its cold limits is confined to regions receiving on the average 10 and 40 inches of rain, or its equivalent in snow, annually, while in the hottest sections of the world these boundaries become 20 and 70 inches. (Figures 3 and 22.)

539. Wheat Yield and Rainfall. Welton and Morris [3] state that under Ohio conditions a decrease in rainfall is accompanied by an increase in yield of wheat. Subnormal rainfall is more beneficial in autumn and early spring than in winter and late spring. They state that the wheat yields in Ohio are probably depressed in most years by too much rainfall.

Sando [4] reports that at the Maryland Agricultural Experiment Station yields above normal are associated with subnormal rainfall for the months of March and May.

Fisher,[5] at the Rothamsted Experiment Station, studied the effect of rainfall on wheat from 1852 to 1918. He found that under the Rothamsted conditions additional rainfall over the average is harmful. The reason for this harmful effect was predominately the harmful effect of the rain in removing the nitrates from the soil.

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[3] Welton, F. A., and Morris, V. H.—"Wheat Yield and Rainfall in Ohio." *Jour. Amer. Soc. Agron.* Vol. 16, No. 11, p. 749. Nov., 1924.

[4] Sando, W. J.—"Climate and Wheat Yields at College Park, Maryland." *Jour. Amer. Soc. Agron.* Vol 15, No. 10, p. 407. Oct., 1923.

[5] Fisher, R. A.—"The Influence of Rainfall on the Yield of Wheat at Rothamsted." *Roy. Soc.* (London) *Phil. Trans. Ser. B.* Vol. 213, p. 141. 1923.

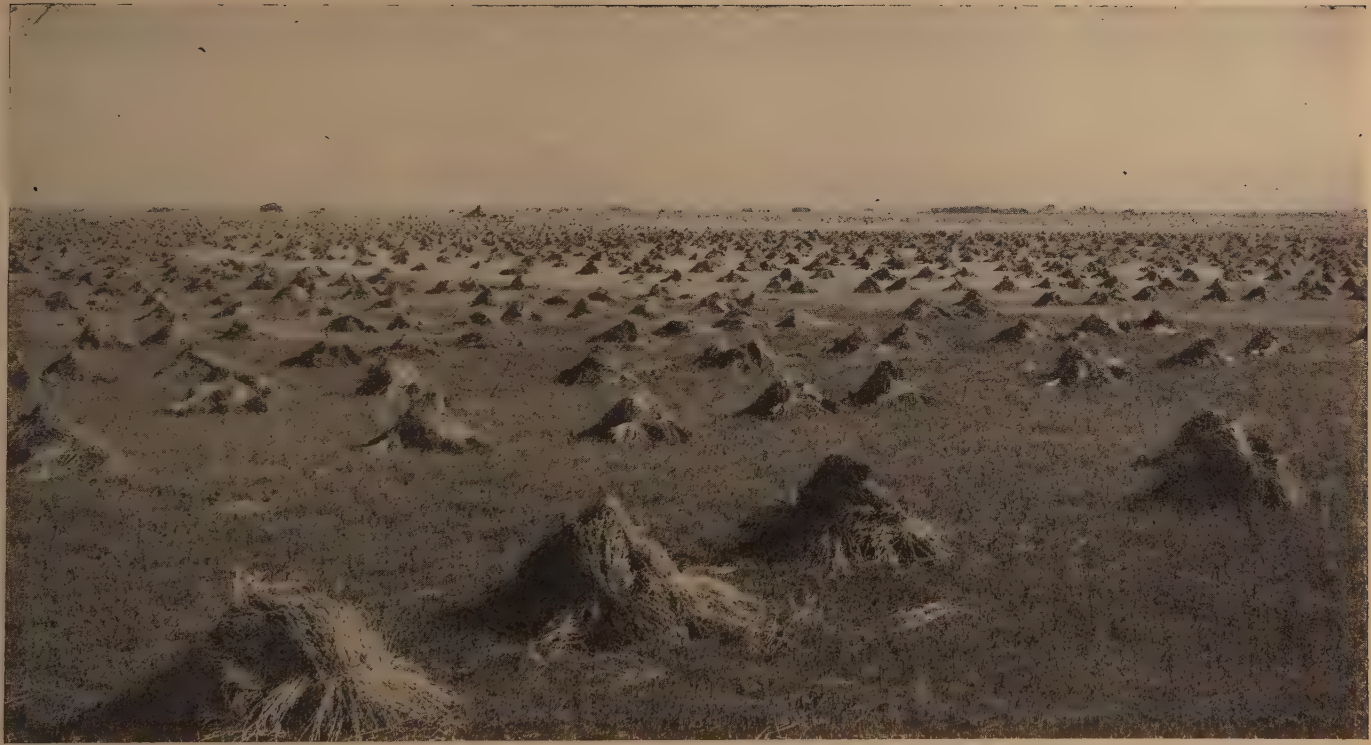

Fig. 105.—Wheat in the shock, southwest central Kansas. *How do you account for the large proportion of land seeded to wheat in this area? What type of wheat is grown? What are the most important changes in wheat production which are taking place in the wheat belt at the present time?*

Ball *et al.*[6] state that the great wheat producing regions of the world are in the drier portions. The average acre yield of wheat in 1909 for a rainfall of 10, 15, 20, 25, 30, 35, 40, 45, 50 and 55 inches was 10, 14, 16, 17.5, 19, 17.5, 16, 14, 11, and 7 bu., respectively.

540. Classification and Types of Wheat. Wheat belongs to the grass family (*Poaceae Gramineae*) and to the tribe *Hordeae* in which one to eight flowered spikelets are sessile and alternate on opposite sides of the rachis thus forming a true spike. Wheat is located in the subtribe *Triticeae,* and in the genus *Triticum,* which is characterized by the solitary two to many flowered spikelets placed sideways against the curved channeled joint of the rachis. Clark *et al.*[7] report the following classification:

GENUS	SPECIES	SUB-SPECIES	COMMON NAME
Triticum	*sativum*	*tenax*	*vulgare Vill.* (common wheat)
			compactum Host. (club wheat)
			turgidum L. (poulard wheat)
			durum Desf. (durum wheat)
		dicoccum Schr. (emmer)	
		spelta L. (spelt)	
	polonicum L. (polish wheat)		
	monococcum L. (einkorn)		

Clark *et al.* also give a key to the species and subspecies of wheat, a careful study of which will give the student the distinguishing characters of the different groups.

WHEAT, *Key to the Species or Subspecies*

1a. Terminal spikelets fertile; palea remaining entire at maturity; spikelets with 2 to 5 fertile florets.
  2a. Glumes shorter than the lemmas, firm; paleas as long as the lemmas. *Triticum sativum Lam.*
    3a. Rachis tenacious; kernels separating from the chaff when threshed.
      4a. Glumes distinctly keeled only in the upper half; lemmas awnless or awns less than 10 cm. long; straw hollow.
        5a. Spikes usually long, dense to lax, somewhat dorsally compressed. *T. aestivum L., T. vulgare Vill.* (common wheat).
        5b. Spikes short, dense, laterally compressed. *T. compactum Host* (club wheat).
      4b. Glumes sharply keeled at the base; lemmas usually awned; awns 10 to 20 cm. long; straw usually solid.
        5a. Glumes and kernels short; kernels ovate, with truncate tips. *T. turgidum L.* (poulard wheat).
        5b. Glumes and kernels longer; kernels usually elliptical. *T. durum Desf.* (durum wheat).
    3b. Rachis fragile; kernels inclosed in glumes when threshed.
      4a. Spikes dense, laterally compressed; pedicel short, slender, usually attached to base of spikelet, shoulders wanting to narrow, usually oblique. *T. dicoccum Schrk.* (emmer).

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[6] Ball, C. R., *et al.*—"Wheat Production and Marketing." *U. S. Dept. Agr. Yearbook 1921,* p. 107.

[7] Clark, J. Allen, *et al.*—"Classification of American Wheat Varieties." *U. S. Dept. Agr. Dept. Bul. 1074,* p. 49. 1922.

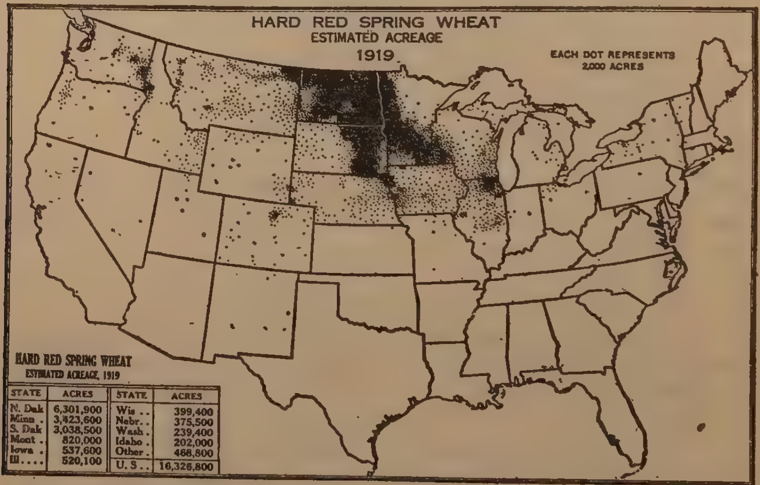
4b. Spikes lax, narrow; pedicel long, wide, attached to face of spikelet below; shoulders wide, square. *T. spelta L.* (spelt).

2b. Glumes as long as or longer than the lemmas, papery, lanceolate; palea of lower flowers half as long as their lemmas. *T. polonicum L.* (Polish wheat).

1b. Terminal spikelets sterile, often scarcely visible; palea falling into 2 parts at maturity; spikelets usually with only 1 fertile floret.

2a. *T. monococcum L.* (Einkorn).

Common wheat is grown much more extensively than any of the others not only in America but also throughout the world. About 85 per cent of the wheat acreage of this country is seeded to the common type. Club wheat comprises only about 7 per cent of our wheat acreage, and Durum slightly less. Neither the Poulard nor the Polish wheats are grown to any commercial extent in America and only to a very limited extent in other parts of the world.



HARD RED SPRING WHEAT
ESTIMATED ACREAGE, 1919

STATE	ACRES	STATE	ACRES
N. Dak	6,301,900	Wis . .	399,400
Minn .	3,423,600	Nebr. .	375,500
S. Dak	3,038,500	Wash .	239,400
Mont .	820,000	Idaho .	202,000
Iowa .	537,600	Other .	468,800
Ill. . . .	520,100	U. S . .	16,326,800

FIG. 106.—The largest acreage of hard spring wheat is grown under sub-humid or semi-arid conditions favorable to high quality. This wheat sets the standard for bread making flour. (U. S. Dept. Agr. Yearbook 1921, page 124.)

541. Wheat Regions. Wheat is divided into 5 distinct classes under the official grain standards act of the United States and the distinct varieties falling within each of these classes are not only distinctly different in appearance and in general habit of growth but also in adaptation, so that the wheats constituting each of these classes are found occupying rather distinct regions.

542. Hard Red Spring Wheat.[8] About 24 per cent of the wheat acreage of the United States is classed as hard red spring wheat.

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[8] Clark, J. A., *et al.*—"The Hard Red Spring Wheats." *U. S. Dept. Agr. Farmers' Bul. 1281.* 1922.

About 14,000,000 acres of this wheat are grown annually in this country. Hard red spring wheat produces flour of high bread making quality. There are 24 distinct varieties of hard red spring wheat, the most important of which are Marquis, Preston (Velvet Chaff), Red Fife, and Haynes Bluestem varieties. A promising new wheat of this class known as Kota was introduced from Russia by Bolley of the North Dakota Agricultural College. The section of the United States which grows hard red spring wheat is shown in Figure 106.

543. Durum Wheat.[9] The second class in the official grain standards for wheat is Durum wheat. The Durums are all spring varieties with long stiff beards and most of them have short, thick, compact heads with white or amber-colored spikes. The grain, which is very hard and usually translucent, is used chiefly for the manufacture of a granular flour from which macaroni, spaghetti, and other similar products are made. Durum varieties have often been referred to as "macaroni" wheat. About 3,500,000 acres are grown annually in the United States. A little over half the Durum wheat grown in the United States is exported. The price of Durum wheat was the same as hard red spring wheat when the price was fixed during the World War. Since 1919 the price of Durum wheat has usually been considerably below that of the hard red spring wheat. There are 12 varieties of Durum wheat grown commercially in the United States. Some of the outstanding varieties are Kubanka, Arnautka, Acme, Monad, Mindum, Peliss, and Pentad. Durum wheats are grown most extensively in the western half of the hard red spring wheat area which is shown in Figure 106.

544. Hard Red Winter Wheat.[10] The third class of wheat under the official grain standards of the United States is hard red winter. About 32 per cent or 18,000,000 acres of the wheat acreage of the United States is of this class. The varieties, all fall sown, have hard red kernels from which a flour of high bread making quality is manufactured. There are 12 varieties of hard red winter wheat grown commercially in the United States. Most of the original strains were introduced from Asia. Turkey, Kharkov, and Kanred are the leading varieties, Turkey and Kharkov being practically identical. The section of the United States growing hard red winter wheat is shown in Figure 107.

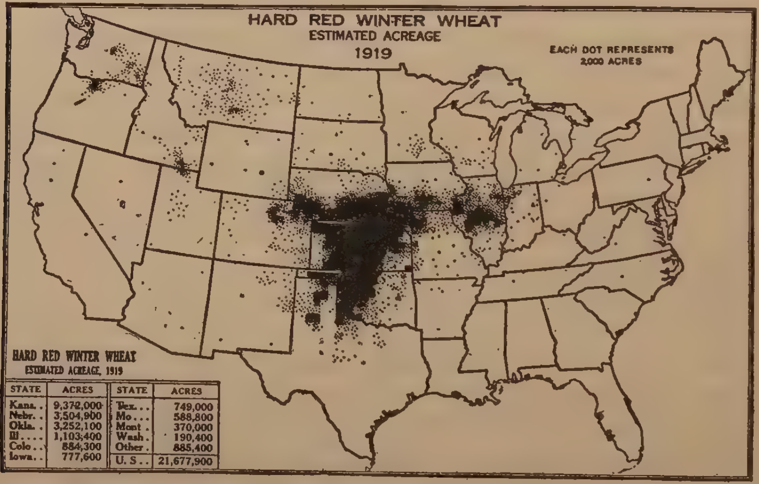
545. Soft Red Winter Wheat.[11] The fourth class of wheat, according to the official grain standards of the United States, is soft

[9] Clark, J. A.—"The Durum Wheats." *U. S. Dept. Agr. Farmers' Bul. 1304.* 1923.

[10] Clark, J. A., *et al.*—"The Hard Red Winter Wheats." *U. S. Dept. Agr. Farmers' Bul. 1280.* 1922.

[11] Clark, J. A.—"The Soft Red Winter Wheats," *U. S. Dept. Agr. Farmers' Bul. 1305.* 1922.

red winter wheat. Most of the wheat grown in the eastern half of the United States belongs to this class. Two varieties of Club wheat with red kernels grown in Washington and Idaho for spring sowing are included in this market class. About 30 per cent of the total wheat acreage, or about 20,000,000 acres are seeded annually to soft red winter wheat varieties. Soft red winter wheat is generally best adapted to humid areas where the winters are not too severe. They can stand more moisture than the hard red winter wheat and are less resistant to drouth. The varieties of this class of wheat have soft to semi-hard red kernels. The flour contains less gluten and more starch than does flour made from the hard red spring and hard red winter wheats and is preferred for pastry making in much of the home baking. Sixty-six varieties are recognized. The most widely grown varieties are Fultz, Fulcaster, Mediterranean, Poole, Red May, Red Wave, and Harvest Queen. The regions growing soft red winter wheat are shown in Figure 108.



STATE	ACRES	STATE	ACRES
Kans. .	9,372,000	Tex. . .	749,000
Nebr. .	3,504,900	Mo. . . .	588,800
Okla. .	3,252,100	Mont .	370,000
Ill. . . .	1,103,400	Wash .	190,400
Colo . .	884,300	Other .	885,400
Iowa . .	777,600	U. S . .	21,677,900

Fig. 107.—Hard red winter wheat occupies nearly half of the total winter wheat acreage of the United States. Wheat of this class ranks next to hard red spring in quality for flour manufacture. (U. S. Dept. Agr. Yearbook 1921, page 125.)

546. White Wheat.[12] The fifth class of wheat, according to the official grain standards, is white wheat. This class includes the white-kerneled varieties, both common and Club. The kernels are really a pale yellow in color. They may be hard and translucent or soft and opaque. Both winter and spring varieties are grown. About 3,000,000 acres are grown annually of this type of wheat. Most of the common white wheats are soft and are used in the making of pastry flour and breakfast foods, or blended with hard wheats for bread making flours. Fifty-two varieties are grown commercially in the United States, 35 of which are spring wheats and 17 winter wheats. Varieties grown on fairly large acreages are Pacific Bluestem, Gold Coin, Baart, Sonora, Defiance, Dicklow, and Dawson. Centers of white wheat production are found in eastern Washington and northern Oregon; western California and western New York, with lesser amounts in Michigan and Idaho. White club wheat is grown in the western part of the United States in areas corresponding to those of the common white wheat.

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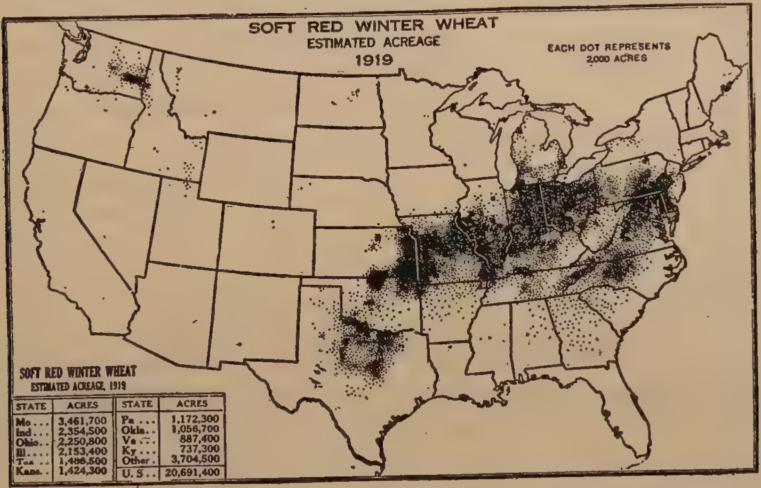
[12] Clark, J. A., *et al.*—"The Common White Wheats." *U. S. Dept. Agr. Farmers' Bul. 1301.* 1922.



SOFT RED WINTER WHEAT
ESTIMATED ACREAGE, 1919

STATE	ACRES	STATE	ACRES
Mo. . . .	3,461,700	Pa. . . .	1,172,300
Ind. . . .	2,354,500	Okla. . .	1,056,700
Ohio. . .	2,250,800	Va. . . .	887,400
Ill.	2,153,400	Ky. . . .	737,300
Tex. . .	1,488,500	Other .	3,704,500
Kans. . .	1,424,300	U. S. . .	20,691,400

FIG. 108.—Soft red winter wheat is grown over a wide area but mostly under humid conditions. (U. S. Dept. Agr. Yearbook 1921, page 126.)

547. Poulard and Polish Wheats. Polish and Poulard wheats are rather striking in appearance. For this reason they have been fraudulently exploited in this country under[13] many different names. Polish wheat has large heads, frequently 6 or 7 inches in length and an inch or more in diameter. The chaff is extremely long and rather thin and papery. The kernels are sometimes ½ inch in length and are very hard, resembling the Amber Durum wheat in color. Poulard wheat has tall, thick, pithy or hollow stems and broad leaves. The kernels are rather short, thick, and humped. Some varieties have white and others have red kernels. Due to the unusual size of kernel of Polish and the branching composite head of Poulard, false stories of the wheat and pictures of individual heads have accompanied offers

[13] Martin, John H.—"Polish and Poulard Wheats." *U. S. Dept. Agr. Farmers' Bul. 1340.* 1923.

to sell this seed at prices ranging from $20 to $60 per bushel. The term "Giant Rye" is sometimes applied to white Polish wheat. "Alaska wheat" is the best known and most widely exploited variety of the Poulard wheats. Only unsatisfactory returns have been obtained from these wheats in all parts of the United States.

548. Emmer and Spelt.[14] Emmer and spelt are kinds of wheat, the kernels of which are not removed from the chaff in threshing. States leading in the production of emmer are South Dakota, North Dakota, Nebraska, Minnesota, and Colorado. The combined area in these grains in 1919 was approximately 166,000 acres with emmer the more important of the two. These grains are used principally as feed for livestock and have a feeding value about equal to oats and somewhat less than barley or corn. They are also used to some extent for making breakfast foods. The hull of emmer and of spelt comprises 20 to 30 per cent of the total weight of the grain. The chemical composition is somewhat similar to oats; with hull or chaff removed, about the same as wheat. They are not suitable for use in this country in the manufacture of bread making flours.

Spelt is grown to only a limited extent, mostly in the eastern half of the United States. It is reported to be more productive than either barley or oats in Maryland and Virginia. Both bearded and beardless, winter and spring varieties of spelt are known. At Arlington, Virginia, spelt has stood up better than wheat, oats, or rye in wet years or on rich and heavy land. White spring or Vernal emmer is the most productive spring variety. Black winter emmer, while productive under some conditions, is not very winter hardy nor resistant to rust or drouth.

Hume[15] reports a 10-year average yield of white spring emmer in comparison with other crops at Brookings. Barley and oats yielded from 10 to 20 per cent more grain than emmer and rye 27 per cent more. Winter wheat equaled emmer in yield while spring wheat gave a yield almost 60 per cent as great. Hume states that it is very evident from the showing made that under South Dakota conditions emmer should be the last crop chosen as a means of increasing the production of feed.

Schmitz[16] reports the total weight of grain produced in Maryland from the highest yielding varieties of wheat, oats, barley, spelt, and emmer.

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[14] Martin, John H., and Leighty, Clyde E.—"Emmer and Spelt." *U. S. Dept. Agr. Farmers' Bul. 1429.* 1924.

[15] Hume, A. N.—"Emmer in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 179.* 1918.

[16] Schmitz, Nickolas—"Winter Oats, Barley, Spelt, and Emmer." *Md. Agr. Expt. Sta. Bul. 200.* 1917.

548a. *The total weight of grain produced per acre by the highest yielding variety of wheat, oats, barley, spelt, and emmer. Maryland.*

NAME OF CROP	NAME OF VARIETY	STANDARD WEIGHT PER BU. (LBS.)	AVERAGE YIELD PER ACRE (BUS.)	TOTAL WEIGHT OF GRAIN PRODUCED PER ACRE (LBS.)
Wheat	Bearded Purple Straw	60	29.87	2412.2
Oats	Dewey	32	51.23	1639.4
Barley	Mammoth Winter	48	34.64	1662.5
Spelt	Alstroum	30	63.23	1896.9
Emmer	Black Winter	30	34.43	1032.9

549. Hard and Soft Wheats. In general, soft and hard wheats have common characteristics though they also have distinct differences.

Soft winter wheat flour is said to have larger and softer grains of starch than flour from hard wheat. The flour has a smooth, powdery texture, a small proportion of gluten, and will absorb a small quantity of water. It is known as soft flour or weak flour and is often called pastry flour.[17]

Flours made from hard wheats, both winter and spring, have harder and smaller grains of starch than that from soft winter wheat. The flour has a granular texture, usually a large proportion of gluten, and will absorb large quantities of water. It is known as a strong or hard wheat flour and is often called bread flour.

Stockham[18] states that the "strength" of a flour is its apparent and potential ability to make a large, good-textured loaf. The strength of a wheat is its production of strong flour. He states that strength is limited largely by varietal inheritance and climate. Hard red spring wheat ranks first followed in order by hard red winter, Durum, soft red winter, and soft white winter. Hard, vitreous kernels are the stronger except in extremely hard and badly shrunken material. External color of wheat is not closely related to strength.

550. Factors Associated with Quality in Wheat. That there are marked differences in the protein content and in the milling qualities of different lots of wheat, even of the same variety, is a fact well established. The day has passed when the farmer grows wheat for its yield per acre only. Protein and gluten tests aid in determining the value of wheat for milling purposes. Practically every car of bread wheat offered for sale in the leading grain markets has a certificate of protein content attached.[19]

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[17] Davis, Laurel E.—"Missouri Flour for Missouri Bread Making." *Mo. Agr. Expt. Sta. Bul.* 227. 1924.

[18] Stockham, W. L.—"Some Factors Related to the Quality of Wheat and Strength of Flour." *N. Dak. Agr. Expt. Sta. Bul. 139*, pp. 65-66. 1920.

The appearance of yellow or of white, mealy, or half mealy, or spotted kernels in hard wheats has been referred to as "yellow berry." The prevalence of this condition has varied greatly from year to year and in different fields. Headden [20] states that yellow berry is not due to over-ripeness nor to exposure after cutting, nor to the action of fungi, nor is it a tendency heritable in wheat, as has been claimed by many authors. He has found no substantiation of the claim sometimes made that climatic conditions favorably influence the development of, or cause yellow berry, but he believes that yellow berry could be easily prevented by the application of sufficient available nitrogen.

The protein and gluten content of wheats is markedly affected by the "yellow berry" condition. Zinn [21] states that there appears to be practically no relation between the crude protein content of wheat and the flour yield, but that the crude protein does seem to be associated with strength of flour as determined by the volume and that the gluten content of the flour is closely correlated with loaf volume.

Sewell and Swanson [22] state that the per cent of protein in wheat is materially affected by the quantity of nitrates in the soil. They state that treatments which produce the largest quantity of nitrates in the soil not only produce the largest yields of wheat and the highest per cent of protein but flour of superior quality considered from the standpoint of the volume of loaf and the texture of the bread.

Davidson and Leclerc [23] found that the use of sodium nitrate in the early stages of growth of the wheat plant stimulated vegetative growth and consequently gave greater yields. Sodium nitrate added to the soil at the time of heading had no influence on vegetative growth but gave a better quality of grain with reference to color and protein.

Neidig and Snyder [24] found that the available nitrogen in the soil has its greatest effect on the protein content and yield when climatic factors are most favorable. Both climate and available nitrogen, they state, play an important part in determining the quality and yield of wheat. Aside from the available supply of nitrogen in the soil they believe that moisture is the chief climatic factor affecting the yield and protein content of wheat.

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[19] Hedges, H.—"Protein as a Wheat Price Factor." *Nebr. Agr. Expt. Sta. Bul. 221.* 1927.

[20] Headden, Wm. P.—"Yellow Berry in Wheat,—Its Cause and Prevention." *Colo. Agr. Expt. Sta. Bul. 205.* 1915.

[21] Zinn, Jacob—"Correlations between Various Characters of Wheat and Flour as Determined from Published Data from Chemical, Milling, and Baking Tests of a Number of American Wheats." *Jour. Agr. Res.* Vol. 23, No. 17, p. 547. Feb. 17, 1923.

[22] Sewell, M. C., and Swanson, C. O.—"Tillage in Relation to Milling and Baking Qualities of Wheat." *Kans. Agr. Expt. Sta. Tech. Bul. 19.* 1926.

[23] Davidson, J., and LeClerc, J. A.—"The Effect of Sodium Nitrate Applied at Different Stages of Growth on the Yield, Composition, and Quality of Wheat." *Jour. Amer. Soc. Agron.* Vol. 9, No. 4, p. 154. Apr., 1917.

[24] Neidig, Ray E., and Snyder, Robt. S.—"The Effect of Available Nitrogen on the Protein Content and Yield of Wheat." *Idaho Agr. Expt. Sta. Res. Bul. 1*, p. 43. 192

In a later publication Neidig and Snyder[25] state that applications of manure to corn in the rotation resulted in a large increase in yield and in the protein content of wheat.

Headden[26] states that the character of the wheat grain depends upon the relative supply of the respective plant foods. Ordinary barnyard manure will not nitrify rapidly enough to affect the composition or physical properties of wheat. Potassium in excessive proportion to nitrogen produces a mealy wheat.

LeClerc ,[27] Shaw and Walters[28] shipped soil from Kansas, Texas, and California to each of the other places and determined the protein content of wheat grown on each of these different soils in each of the 3 states. They concluded that the soil nitrogen content had very little direct influence upon the nitrogen content of the grain and that the climatic factors are sufficient to completely overshadow the soil factor.

Kiesselbach[29] states that delayed planting reduced grain yields without a compensating increase of baking value. He states that no effort to control baking value through date of planting would seem to be justifiable. Harvesting wheat before maturity in the early and late dough stages during a 4-year period failed to increase the protein content of the grain or to give consistently superior milling and baking results. Manure applications at the rate of 8 tons every 4 years failed to affect the milling and baking qualities of Turkey Red winter wheat although it increased the grain yields 4½ bushels per acre.

Mangels[30] states that temperature in June and July is probably the principal factor in determining the average protein content of the North Dakota wheat crop. He found that wheat on timothy and clover sod had a higher protein content than wheat on corn land. Legume rotations, in general, favor a high protein content. Early harvested wheat may have a higher protein content, but the increase in protein content does not compensate for the loss of yield and lower grade which results from early cutting.

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[25] Neidig, Ray E., and Snyder, Robt. S.—"Relation of Yield and Protein Content of Wheat to the Nitrogen Content of the Soil in 10 Different Years of Systems of Cropping." *Idaho Agr. Expt. Sta. Res. Bul. 5.* 1926.

[26] Headden, Wm. P.—"A Study of Colorado Wheat." *Colo. Agr. Expt. Sta. Bul. 244.* 1918.

[27] LeClerc, J. A.—"Tri-local Experiments on the Influence of Environment on the Composition of Wheat." *U. S. Dept. Agr. Bur. Chem. Bul. 128.* 1910.

[28] Shaw, G. W., and Walters, E. H.—"A Progress Report upon Soil and Climatic Factors Influencing the Composition of Wheat." *Calif. Agr. Expt. Sta. Bul. 216.* 1911.

[29] Kiesselbach, T. A.—"Winter Wheat Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 31.* 1925.

[30] Mangels, C. E.—"Protein Content of North Dakota Wheat." *N. Dak. Agr. Expt. Sta. Bul. 191.* 1925.

Bailey [31] found that wheat grown in 1911 with a rainfall of 12 to 14 inches produced a flour with 13.47 per cent of crude protein; 14 to 16 inches, 12.62 per cent; 16 to 18 inches, 12.43 per cent; 18 to 20 inches, 11.91 per cent; 20 to 22 inches, 11.73 per cent. He credits variations in composition of the hard spring wheats largely to environment, including climate and soil.

Stockham [32] states that the composition of the kernel is influenced somewhat by the soil but more largely by the moisture conditions. The best conditions for growth result in a larger yield per acre, but a lower protein content and lower strength than that produced where conditions are not favorable because of either insufficient or excessive moisture.

A Kansas bulletin [33] states that it requires 270 pounds, or 4½ bushels, of wheat testing about 58 pounds to produce 196 pounds or 1 barrel of 100 per cent straight flour. The range is from 4 bushels 25 pounds of wheat to 5 bushels of different qualities of wheat to produce a barrel of flour.

551. Recommended Varieties of Wheat. There are many different varieties of wheat available to growers and the variety which can be expected to be most satisfactory will vary with the

551a. Recommended varieties of winter wheat.

N. E. States	Soft White	Dawson's Golden Chaff
Mich., Ohio, N. Y., Pa..	Soft White and Red	Redrock, Fulcaster, Trumbull, Leaps Prolific
Iowa, Ind., Ill., Neb., Kans., Minn., S. Dak., Wis., Tex., Oklahoma, Cal., N. Mex., Utah, Wyo.	Hard Red Winter	Kanred, Ill. Red., Ioturk, Purkoff Minturki, S. D. 144, Neb. 6 and 60, Wis. Ped. No. 2, Some Fulcaster, Fultz in the East
Del., N. Jer., Md., Va., W. Va., S. Car., Ky., Tenn., Mo., Ark., other southern states.	Soft Red Winters	Fultz, Fulcaster, Leaps Prol., Gladden Trumbull, Corrells Prof., Red May
Cal., Wash., Oregon, Idaho	Hard White and Red	Triplet, Hybrid 128, Turkey Albit, Redit

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[31] Bailey, C. H.—"Minnesota Wheat Investigations. Series 1. Milling, Baking, and Chemical Tests. Crop of 1911." *Minn. Agr. Expt. Sta. Bul. 131.* 1913.

[32] Stockham, W. L.—"Some Factors Related to the Quality of Wheat and Strength of Flour." *N. Dak. Agr. Expt. Sta. Bul. 139*, pp. 66-69. 1920.

[33] Fitz, L. A.—"The Milling Value of Kansas Wheat." *Kans. State Bd. Agr. (Quart.) Rpt.* Vol. 39, No. 155, p. 200. Sept., 1920.

environmental conditions. Some of the varieties which are recommended most generally in the different sections of the country are as shown in Table *551a*.

Spring wheat varieties generally recommended by agronomists in the spring wheat section include Marquis, Kota, and Progress (common wheats), and Kubanka and Mindum (Durum wheats). Dicklow, Federation, Bluestem, and Baart are recommended in western and mountain states.

552. Time of Seeding Wheat. The date of seeding wheat which may be expected to give the best results will vary with climatic and soil conditions. Time of seeding may be a much more important factor under some conditions than others. **(935.)**

Matthews [34] reports a date of seeding test with Marquis wheat continued for 13 years on summer fallowed land in Saskatchewan, Canada, with yields per acre and number of days to mature after seeding. Five seedings were made. Yields for the seedings at weekly intervals in order from first to last were 24.9, 27.9, 24.4, 24.7, and 23.3 bushels. The average number of days to mature in the same order were 125, 118, 115, 113, and 109. The earliest seeding was made as soon as possible after spring work opened up, usually about April 15. See Tables *552a* and *552b*.

553. Rate of Seeding Winter Wheat. The rate of seeding winter wheat which gives the largest returns varies considerably for different parts of the country, over twice as much seed being recommended per acre in some sections as in others. Many comparisons have been made in different states and these results are summarized in Table *553a* on pages 456-457.

A survey in Kansas indicated that in the western and drier sections of the country, where the rainfall was 18.68 [35] inches, the average rate of seeding winter wheat was 3.18 pecks per acre; in the central section, where the rainfall was 24.8 inches, the rate of seeding was 4.37 pecks; and in the eastern section, where the rainfall was 35.8 inches, the rate of seeding was 5.25 pecks per acre.

It has been suggested that the date of seeding probably had an important influence on the rate of seeding which gave the best returns, and comparisons have been made at several stations to determine whether or not such a relation does exist.

Jardine [36] reports studies continued for 3 years at Manhattan,

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[34] Matthews, V.—"Correlation of Time of Seeding and Yields of Spring Grain." *Canada Expt. Farms. Seasonable Hints. Prairie Ed. No. 37.* Mar., 1927.

[35] Mohler, J. C.—"Wheat in Kansas." *Kans. State Bd. Agr. (Quart.) Rpt.* Vol. 39, No. 155, p. 63. Sept., 1920.

[36] Jardine, W. M.—"Effect of Rate and Date of Sowing on Yield of Winter Wheat." *Jour. Amer. Soc. Agron.* Vol. 8. No. 3. p. 165. May-June, 1916.

552a. *Time of seeding winter wheat as affecting yield; bushels per acre. Dates approximate in some cases. Summary.*

STATION	NO. OF YEARS	8/1	8/15	9/1	9/15	10/1	10/15	11/1	11/15
Mont. (Moccasin)	[a] 4	....	27.2	32.6	29.2	24.4	21.1	....	....
S. Dak. (Newell)	[a] 5	....	....	....	34.1	35.5	33.1	30.7	....
S. Dak. (Highmore)	[a] 3	....	....	....	26.7	22.8	25.9	....	....
Wyo. (Sheridan)	[a] 6	26.6	30.5	32.1	34.2	35.7	32.0	24.9	....
Wyo. (Archer)	[a] 6	....	22.3	24.0	21.8	15.2	12.3	....	....
Colo. (Akron)	[a] 7	....	....	....	24.1	23.2	14.9	14.6	....
Kans. (Hays)	[a] 4	....	....	....	26.5	29.2	17.1	12.9	....
Tex. (Amarillo)	[a] 5	....	....	....	....	12.7	13.0	12.0	10.9
Okla. (Lawton)	[a] 5	....	....	24.9	26.5	25.5	26.4	....	16.2
Ore. (Moro)	[a] 8	....	....	....	33.1	32.9	32.4	30.2	27.7
Idaho (Aberdeen)	[a] 6	....	10.1	11.0	14.9	10.4	7.6	....	....
S. Dak. (Highmore)	[b] 9	17.9	16.0	19.2	19.3	15.8	13.5	12.8	10.8
S. Dak. (Brookings)	[b] 4	....	31.0	38.7	35.1	28.0	22.7	17.7	....
Ohio	[c] 16	....	....	26.7	32.1	32.7	26.3	18.2	....
W. Va.	[d] 3	....	....	28.3	31.1	29.6	21.5	15.1	....
Mich.	[e] 2	....	21.5	19.0	9.8	6.3	10.0	6.5	....
Ore.	[f] 6	....	....	....	33.8	33.4	31.9	25.8	22.4
Idaho	[g] 5	26.5	33.0	36.9	32.5	23.2	21.6	....	....
Kans.	[h] 3	....	....	....	....	36.3	27.8	20.24	19.04
Nebr.	[i] 3	....	....	....	28.8	28.3	23.8	20.5	17.4

[a] Martin, John H. *Jour. Amer. Soc. Agron.* Vol. 18, No. 3, pp. 214-216. Mar., 1926.
[b] Hardies, E. W., and Hume, A. N. *S. Dak. Agr. Expt. Sta. Bul. 222.* 1927.
[c] Thatcher, L. E. *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. VII, Nos. 9 and 10, pp. 141-143. Sept.-Oct., 1922.
[d] Odland, T. E. *W. Va. Agr. Expt. Sta. Bul. 200.* 1926.
[e] Weston, J. W., *et al. Mich. Agr. Expt. Sta. Spec. Bul. 116,* p. 39. 1922.
[f] Stephens, D. E., and Hyslop, G. R. *Ore. Agr. Expt. Sta. Bul. 190.* 1922.
[g] Moss, W. A. *Idaho Agr. Expt. Sta. Bul. 145.* 1926.
[h] Jardine, Wm. M. *Jour. Amer. Soc. Agron.* Vol. 8, No. 3, p. 165. May-June, 1916.
[i] Kiesselbach, T. A. *Nebr. Agr. Expt. Sta. Res. Bul. 31,* p. 88. 1924 .

552b. *Time of seeding spring wheat. Yields bushels per acre. Dates approximate in some cases. Summary.*

STATION	NO. OF YEARS	3/1	3/15	4/1	4/15	5/1	5/15	6/1	6/15
N. Dak. (Willston) [a]	4					34.4	29.7	20.2	
S. Dak. (Newell) [a]	3				22.2	16.5	15.2		
S. Dak. (Highmore) [a]	6			24.2	20.2	14.1			
S. Dak. (Highmore) [a]	4			15.6		10.3			
Wyo. (Sheridan) [a]	6			13.5	14.1	9.5	5.2	0.5	0.0
Wyo. (Archer) [a]	6				11.0	10.1	8.0		
Wash. (Lind) [a]	7		10.7		9.4	7.1			
Ore. (Moro) [a]	7		17.3		12.3				
S. Dak. (Highmore) [b]	8	11.7	19.9	18.5	17.9	11.3	7.6	0.9	
S. Dak. (Highmore) [h, b]	8	9.8	20.1	21.2	21.3	16.3	10.2	6.5	
Nebr.[c]	17		12.3	12.1	9.0	6.6			
Ill.[d]	5	26.4	22.6	16.4	13.3				
Canada (Sask.) [e]	2				26.0	22.6	21.8	20.9	
Mont.[f]	3				57.7	52.0	44.1	27.9	
Nebr.[g]	7			15.8	12.1	9.0			

[a] Martin, John H. *Jour. Amer. Soc. Agron.* Vol. 18, No. 3, pp. 218-219. Mar., 1926.
[b] Hardies, E. W., and Hume, A. N. *S. Dak. Agr. Expt. Sta. Bul. 222.* 1927.
[c] Zook, L. L. *Nebr. Agr. Expt. Sta. Bul. 213.* 1926.
[d] Stark, R. W. *Ill. Agr. Expt. Sta. Bul. 287.* 1927.
[e] Munro, W. A. *Canada Expt. Farms, Rosthern (Sask.) Sta. Rpt. Supt. 1925*, p. 20.
[f] Atkinson, Alfred. *Mont. Agr. Expt. Sta. Bul. 84.* 1911.
[g] Kiesselbach, T. A., and Lyness, W. E. *Nebr. Agr. Expt. Sta. Bul. 201.* 1924.
[h] Yield for durum wheat.

553a. Effect of rate of seeding winter wheat on yield of grain. Rate of seeding in pecks and yields in bushels per acre. Summary.

STATION	No. of Years	1	2	3	4	5	6	7	8	9	10
Indiana[a]	6	...	23.5	27.6	28.9	30.8	33.0	34.3	33.6	...	...
Ohio[b]	22[q]	...	...	25.7	27.3	27.8	28.3	28.3	29.1	28.9	28.5
Mo.[c]		...	...	15.7	15.0	16.5	15.7	15.8	17.5	16.3	15.9
Mo.[c]		...	...	14.8	14.9	15.6	15.4	16.3	15.2	15.4	...
Wis.[d]	7	...	...	...	33.6	...	32.9	...	33.9	...	...
Nebr.[e]	16	...	32.3	31.6	32.0	32.7	...	...	...	...	...
	9	23.8	28.6	28.4	28.3	29.1	...	...	...	...	...
U. S. Dept. Agr.[f]											
S. Dak. (dry land)	4	...	22.3	25.3	26.2	25.7	25.8	26.5			
S. Dak. (irrigate)	3	...	...	21.7	24.0	25.0	24.0	...			
Virgina[g]	2	...	22.2	23.0	26.4	26.2	26.1	25.7	21.9	...	...
Mont.[h]	6	...	25.8	31.8	31.2	28.5	27.4	...	26.9	...	...
U. S. Dept. Agr.[i]											
Nephi, Utah	4	...	13.17	14.42	17.0	18.61	16.77	...	...	...	...
Ore.[j]	6[q]	...	27.0	28.2	28.3	29.4	28.1	28.7	27.9	...	...
W. Va.[k]	3	...	...	...	24.4	27.2	28.7	29.5	31.4	...	...
Nebr.[l]	5	...	...	28.6	30.4	30.5	31.5	...	30.7	...	...
Idaho[m]	4	...	21.1	24.0	26.5	25.9	...	...	...	...	...
S. Dak.[n]	10	...	22.3	25.1	26.5	28.1	27.7	27.9	...	...	...
Wash., D. C.[r, o]	11[q]	...	21.8	24.8	26.4	26.1	26.6	26.0	26.0	...	...
Mont. (Mocassin)[r]	4[r]	...	28.1	31.7	30.3	27.4	27.0	26.4	...	...	...
S. Dak. (Newell)[r]	4[q]	...	21.8	24.5	25.3	24.4	24.3	24.8	...	...	...
S. Dak. (Highmore)[r]	3[q]	...	11.4	15.4	20.9	22.5	18.6	...	...	...	...
S. Dak. (Brookings)[r]	5[q]	...	25.8	29.2	29.7	31.3	31.0	28.9	...	...	...
Wyoming (Sheridan)[r]	6[q]	...	29.4	29.4	31.5	32.9	34.0	...	33.7	...	...
Wyoming (Archer)[r]	8[q]	...	15.9	17.2	17.1	18.3	17.2	...	...	...	...
Colo. (Akron)[r]	6[q]	14.5	18.6	19.7	19.7	20.6	22.1	...	...	...	...

Kansas (Hayes)[r]	4[q]	17.1	21.2	22.7	23.4	...	...	...	...	...	...
Tex. (Amarillo)[r]	6[q]	...	12.2	12.7	13.3	13.4	...	...	...	...	...
Okla. (Lawton)[r]	5[q]	...	20.7	22.2	22.4	22.1	22.2	...	...	...	...
Wash. (Lind)[r]	6[q]	...	11.2	11.9	11.8	11.4	11.3	10.6	10.2	...	...
Ore. (Moro)[r]	8[q]	...	28.3	29.1	29.3	30.0	29.1	29.6	29.1	...	...
Idaho (Aberdeen)[r]	5[q]	...	15.7	18.1	19.5	17.4	...	...	...	...	...
Utah (Nephi)[r]	6[q]	...	19.5	22.1	24.7	26.5	27.7	...	...	...	...
Canada (Sask.)[p]	2[q]	...	15.3	...	21.3	...	22.3	22.3	19.6	...	21.4

[a] *Ind. Agr. Expt. Sta. Ann. Rpt. 36,* p. 52. 1923.

[b] *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 7, No. 9-10, p. 139. Sept.-Oct., 1922.

[c] *Mo. Agr. Expt. Sta. Bul. 188,* 1921.

[d] *Wis Agr. Expt. Sta. Bul. 339,* p. 108. 1921.

[e] *Nebr. Agr. Expt. Sta. Bul. 193,* p. 24. 1923.

[f] *U. S. Dept. Agr. Dept. Bul. 1039,* pp. 23 and 50. 1922.

[g] *Va. Agr. Expt. Sta. Bul. 216.* 1917.

[h] *Mont. Agr. Expt. Sta. Bul. 110.* 1916.

[i] *U. S. Dept. Agr. Dept. Bul. 157,* p. 30. 1915.

[j] *Ore. Agr. Expt. Sta. Bul. 190.* 1922.

[k] *W. Va. Agr. Expt. Sta. Bul. 200.* 1926.

[l] *Nebr. Agr. Expt. Sta. Res. Bul. 31,* p. 109. 1924.

[m] *Idaho Agr. Expt. Sta. Bul. 145.* 1926.

[n] *S. Dak. Agr. Expt. Sta. Bul. 222.* 1927.

[o] *U. S. Dept. Agr. Dept. Bul. 1309.* 1925.

[p] *Canada Expt. Farms, Rosthern (Sask.) Sta. Rpt. Supt.* p. 21. 1925.

[q] The yields are net; that is, the seed planted is taken from the gross yield.

[r] Martin, John H. "Factors Influencing Results from Rate and Date of Seeding Experiments with Wheat in the Western United States." *Jour. Amer. Soc. Agron.* Vol. 18, No. 3, pp. 198-201. Mar., 1926.

Kansas, the seedings being made at weekly intervals through 8 weeks with rates varying from 2 to 8 pecks.

553b. Date of seeding winter wheat as influencing the best rate. Rates of seeding in pecks per acre and yields in bushels. Kansas.

DATES	2	4	6	8	AVERAGE
Sept. 15.............	44.65	43.89	42.95	43.54	....
Sept. 22.............	35.62	36.55	35.89	34.42	35.62
Sept. 30.............	31.16	34.44	38.56	40.67	36.30
Oct. 6..............	31.04	35.15	36.94	36.65	34.94
Oct. 13..............	22.35	27.44	30.18	31.22	27.80
Oct. 20..............	14.97	20.83	21.82	23.42	20.26
Oct. 28..............	13.16	18.74	22.41	26.66	20.24
Nov. 4..............	....	....	15.25	22.83	19.04

Thatcher [37] reports rate and date of seeding tests with winter wheat at the Ohio station continued through a 7-year period. The yields given in Table *553c* are net yields per acre.

553c. Date of seeding winter wheat as influencing the best rate. Rates of seeding in pecks per acre and yields in bushels. Ohio.

RATE, PKS.	SEPT. 15	SEPT. 25	OCT. 5	OCT. 15	OCT. 25	7-YR. AVERAGE
6	29.4	34.8	33.8	35.0	26.6	31.9
8	30.4	35.3	36.8	34.6	27.9	33.0
10	33.0	36.2	36.1	36.0	28.5	34.0
Average for date.	31.0	35.4	35.6	35.2	27.7	33.0
Wt. per bu.	60.8	60.4	59.9	59.5	58.5	59.8

Martin [38] reports a test of rate and date of seeding with hard red winter wheat at Sheridan, Wyoming; Akron, Colorado; Hays, Kansas; Lawton, Oklahoma; and Moro, Oregon. He states that the outstanding result of the combined experiment is that rate and date of seeding are practically independent. A thin seeding has produced lower yields at all stations. Rates of seeding show similar trends for all dates. There is a somewhat wider spread in the yields from the different rates of seeding early sown than for the late sown wheat. He states also that it is a well known fact that early sown wheat tillers more than late sown wheat, but these results indicate that it is safer to sow thickly than to depend upon tillering to produce a full stand. Martin states that the optimum date of seeding for winter wheat is independent of soil type, annual precipitation, and rate of seeding, but is related somewhat to temperature even though the temperature conditions do not apply in all sections.

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[37] Thatcher, L. E.—"Wheat, Cultural Notes." *Ohio Agr. Expt. Sta. Bul. 373.* June, 1923.

[38] Martin, John H.—"Factors Influencing Results from Rate and Date of Seeding Experiments with Wheat in the Western United States." *Jour. Amer. Soc. Agron.* Vol. 18, No. 3, p. 225. Mar., 1926.

Grantham[39] states that early seeding of winter wheat is accompanied by a higher rate of tillering than late seeding. The rate of seeding, or space per plant, is also a factor in determining the number of tillers. The thicker the seeding the fewer the tillers per plant. Close seeding results in earlier maturity and shorter spikes. On fertile soil wheat may be sown later than on thin soil and tiller equally well. Varieties of wheat differ considerably in their tendency to tiller. Bearded wheats as a class tiller more than smooth wheats. The factors of environment seem to have less effect on the rate of tillering of bearded varieties.

554. Rate of Seeding Spring Wheat. Rate of seeding experiments with spring wheat include seedings made with from 2 to 16 pecks per acre. The summary of results from a number of stations is given in Table *554a*.

Montana found that spring wheat yields were reduced 1.5 per cent for each day seeding was delayed after the period between April 29 and May 16. They state that while the Marquis wheat should be sown at the rate of about 4 pecks per acre, the larger-grained varieties required 5 pecks.[40]

Special "Marvelous" Tillering Varieties. Occasionally, a dealer advertises a wheat variety to be so prolific that its rate of seeding need be but a small part of that for ordinary varieties. Such varieties have been tested under various names. No advantage was found in any case for the "marvelous" or "miracle" wheat. In general, the yield of these varieties at all rates of seeding was less than that secured from the varieties generally recommended.

555. Drilling and Broadcasting. The yield secured by drilling seed wheat has been compared with that secured by broadcasting the seed at a number of stations. The results are presented in Table *555a*.

556. Width of Drill Rows. A number of stations determined the effect of varying the distance between the drill rows. The results of such comparisons are reported in Table *556a*.

557. Cross Drilling. Drilling one way, as compared with drilling the same amount of seed per acre but seeding half of it at a time at right angles across the field, or cross drilling, has been compared at several stations with the results shown in Table *557a*.

Drilling east and west showed no appreciable advantage over

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[39] Grantham, A. E.—"The Tillering of Winter Wheat." *Del. Agr. Expt. Sta. Bul. 117*, p. 118. 1917.

[40] Linfield, F. B.—"Some New Facts from the Montana Experiment Station." *Mont. Agr. Expt. Sta. Ann. Rpt. 32*, p. 42. 1925.

554a. *Rate of seeding spring wheat; seed in pecks and yields in bushels per acre. Summary.*

STATION	NO. OF YEARS	2	3	4	5	6	7	8	12	16
Nebr. Bul. 193	10	10.9		14.7	14.7			Durum		
S. D. Bul. 201										
(Kubanka)	7		9.4	14.4	16.3	16.4	17.9	Common		
(Preson)	9			16.0	16.5	17.1	17.3	Common		
S. D. Bul. 222	7			11.5	14.0	15.5	15.6	15.8	Common	
	7			16.3	15.5	18.5	19.4	18.4	Durum	
U. S. D. A. Bul. 1093										
Belle Fourche, S. D.			19.3	19.0	19.4	18.9	18.7	Common		
Mont. Bul. 120		39.9		51.6		55.6		57.5	58.5	58.2
								Common		
N. D. (Williston)[b]	7[a]		26.7	31.5	31.0	32.0	Common			
N. D. (Edgely)[b]	7[a]	8.2	9.7	9.9	10.3	10.2	10.5	9.7	9.6	Durum
N. D. (Edgely)[b]	7[a]	8.4	9.5	11.3	11.6	11.6	11.7	11.8	10.7	Common
S. D. (Newell)[b]	5[a]		18.5	18.0	18.1	15.4	16.9	Durum		
S. D. (Highmore)[b]	4[a]	16.1	19.9	21.5	23.2		Durum			
S. D. (Highmore)[b]	4[a]	11.5	11.6	14.5	12.2		Common			
S. D. (Brookings)[b]	6[a]			15.8	17.8	17.6	19.0	Durum		
Wyo. (Sheridan)[b]	7[a]	12.3	11.8	12.4	11.7	11.3	10.6	Durum		
Wyo. (Archer)[b]	7[a]	14.6	14.8	15.2	14.5	14.2				
Colo. (Akron)[b]	8[a]	15.1	15.5	15.9	15.1	15.0		Durum		
Texas (Amarillo)[b]	6[a]		7.7	7.6	7.8	7.5		Durum		
Texas (Amarillo)[b]	6[a]		6.6	6.4	6.0	5.5		Common		
Washington (Lind)[b]	7[a]	8.9	9.8	9.9	9.5	9.2	8.6	8.6	Common	
Ore. (Moro)[b]	7[a]	15.6	15.6	16.1	16.9	16.8	15.4	16.7	Common	

[a] Net yields; seed planted is deducted from the gross yield.

[b] Martin, John H. "Factors Influencing Results from Rate and Date of Seeding Experiments with Wheat in the Western United States." *Jour. Amer. Soc. Agron.* Vol. 18, No. 3, pp. 206-209. Mar., 1926.

555a. *Drilling seed wheat vs. broadcasting. Yield in bushels per acre. Summary.*

STATION	DURATION	DRILL	BROADCAST
	Winter Wheat		
Nebr. Bul. 160			
(North Platte)	4	20.6	9.7
(Lincoln)	4	38.2	38.2
Nebr. Bul. 193	4	22.8	18.4
Nebr. Bul. 193	9	28.4	20.9
Nebr. Res. Bul. 31	5	29.7	24.4
Ohio Bul. 298	5	28.7	24.9
Iowa Bul. 133	4	29.1	24.9
Idaho Bul. 145	4	26.3	21.5
Ont. (Canada) Bul. 332	7	39.8	36.7
	Spring Wheat		
Wis. Bul. 339	7	18.7	18.6
Nebr. Bul. 160	4	16.3	10.5 Dry land
Nebr. Bul. 193	8	11.1	8.4
Ont. (Canada) Bul. 332	5	13.2	13.4

556a. *Spacing of drill rows as affecting the yield of wheat. Spacing in inches, yield in bushels per acre. Summary.*

STATION	DURATION YRS.	2	3	4	6	8	10	12	14	16
Ill. Bul. 214										
(DeKalb)	3			28.9		30.0				
(Urbana)	2			28.0		29.1				
Ohio Bul. 373	8		10.3	34.8		35.6				
Va. Bul. 216	2	21.0		23.8	21.7	21.9				
Kans. Tech. Bul. 13	4					27.9	28.4	28.2	27.7	26.3
Nebr. Res. Bul. 31	5			29.8		29.7				

557a. *Cross drilling wheat as affecting the yield of grain. Summary.*

STATION	DURATION YRS.	DRILLED ONE WAY		CROSS DRILLED	
		Grain	Straw	Grain	Straw
Ohio Bul. 298	3	23.91	2576	24.67	2620 W. Wheat
U. S. D. A. Bul. 157	4	15.09	....	17.08	W. Wheat
Va. Bul. 216	2	23.07	....	24.23	W. Wheat
N. Dak. Bul. 10		11.9	....	11.4	Sp. Wheat

drilling north and south with either the common or furrow drill at Hayes, Kansas.[41]

558. Depth of Seeding. Albright[42] states that theoretically the shallower the wheat kernel is planted, within reasonable limits, the more normally its root system will develop. It has been noted that shallow drilling often results in somewhat irregular germination. He states that it is usually well to set the drill so that practically all the seed may lie on a firm bottom with moisture beneath and around it.

558a. Yields of wheat seeded at different depths as reported from a number of stations. Depth of seeding wheat. Summary.

STATION	NO OF YEARS	CROP	1 IN.	2 IN.	3 IN.	4 IN.
Ohio Bul. 298	5	Winter Wheat	28.7	28.7	28.5	
Ark. Bul. 121	3	" "	25.4	21.6	20.0	
Idaho Bul. 145	4	" "	26.3		26.7	
Belle Fourche, S. Dak. *U. S. D. A. Bul. 1039*	2	" "	30.2	30.4		
Canada[a]	3	Spring Wheat	22.0	45.0	43.0	43.0

[a] *Report of the Dominion Expt. Farm, Canada*, p. 68, 1915.

559. Pasturing Winter Wheat. Kiesselbach[43] states that pasturing a field of rank growing Turkey Red wheat in the spring of 1919 from March 31 to April 30 increased the yield of grain 4.7 bushels per acre or 33 per cent. The unpastured wheat was 1 foot high when the cattle were removed from the pastured wheat. The unpastured wheat lodged badly. Wheat which was cut back with a mowing machine to a height of 5 inches at this time yielded 2.1 bushels or 15 per cent more per acre than the unmowed field. Lodging was somewhat reduced by both the pasturing and the mowing. In 3 other years when no lodging occurred, pasturing from the time the wheat was 9 inches high until April 30 reduced the average yield 12.9 bushels per acre, or 32 per cent. Kiesselbach states that under conditions of very rank growth lodging can sometimes be advantageously reduced by pasturing or cutting back. The danger lies in the grazing or in cutting off the wheat heads while still in the boot. Many of the heads have reached an elevation of 2 inches above ground by April 30. In another experiment covering a 6-year period clipping the wheat with a mower on April 30 to 5, 3, and 1½ inches in height above the ground yielded 27.2, 25.4, and 20.1 bushels per acre compared to 28.7 bushels for the unclipped wheat. Clipping on May 5 to these same heights yielded 19.9, 16.5, and 11.0 bushels. Wheat clipped on May 10 produced 14.0, 10.8, and 7.3 bushels, respectively, while on May 15 the yield was 8.1, 5.7, and 3.3 bushels per acre, respectively. The grain yield reductions were accompanied by a thinning of the wheat stand, a reduction in mature height and in straw weight, and by delayed maturity.

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[41] Swanson, A. F.—"Cereal Experiments at the Fort Hayes Branch Station. Hayes, Kans. 1912 to 1923." *U. S. Dept. Agr. Tech. Bul. 14.* 1927.

[42] Albright, W. D.—"Securing Good Germination in the Peace River District." *Canada Expt. Farms. Seasonable Hints. Prairie Ed. No. 37.* Mar., 1927.

[43] Kiesselbach, T. A.—"Winter Wheat Investigations." *Nebr. Agr. Expt. Sta. Res. Bul. 31*, p. 11. 1925.

In a Kansas survey[44] in which 1072 farmers reported, 726 said that they were in the habit of pasturing their wheat regularly, 216 did so occasionally, and 130 did not pasture at all. A relatively greater number pastured their wheat in central and western Kansas than followed this practice in the eastern part of the state. Pasturing in the fall and winter was the most common. Pasturing started when the plants were 3 to 5 inches in height, or from 6 to 8 weeks after seeding, or when the plants had stooled well. Most of the men believed that pasturing bottom lands was beneficial as it reduced lodging. The rate of pasturing was 5 to 15 acres of wheat per head for horses, 4 to 10 acres per head for cattle, and 2 to 3 acres per head for hogs. The majority of the men preferred to pasture wheat with horses and cattle rather than with hogs or sheep. The latest date in the spring on which it was thought advisable to pasture wheat was given as March 15 by 297 of these men, April 15 by 383 men, and May 1 by 72 men.

At the Kansas station the yield of wheat fall pastured was 26.15 bushels per acre; spring pastured, 27.78 bushels; and wheat not pastured, 29.6 bushels. In these experiments cattle were not allowed on the ground when it was wet nor was the wheat eaten down for any long period. They find also that pasturing wheat delays maturity from several days to a week.

Oklahoma[45] reports that as a 2-year average wheat not pastured at all produced 2.45 bushels per acre more than that pastured till the end of February, 3.5 bushels more than that pastured till the end of March, and 9.66 bushels per acre more than that given heavy, late, close pasturing. They state that pasturing wheat which has made but a normal growth, even to a moderate degree, has a tendency to lower the yield of grain and straw, but the value received in pasture would in most cases cover the difference in yield of grain. Their results indicate that in Oklahoma it is advisable to pasture wheat where a heavy top growth had been made, although stock should be removed by March 1 or March 15 at the latest.

[44] Mohler, J. C.—*Kans. State Bd. Agr.* (*Quart.*) *Rpt.* Vol. 39, No. 155, pp. 73-77. 1920.

[45] Burtis, F. C., and Moorhouse, L. A.—"Wheat Growing." *Okla. Agr. Expt. Sta. Bul.* *65.* 1905.

560. Labor Requirement for Wheat. The Ohio station[46] reports data relative to the amount of labor required per acre in wheat production.

560a. Wheat: Labor requirements for production.

Operation and Implement	Labor per Acre		
	Man Hours	Horse Hours	Acres Covered in 10-Hour Day
Disking, 7 foot, 4 horses	0.7	2.8	14.0
Drilling, 7 foot, 3 horses	0.9	2.7	11.2
Drilling, 63 inch, 2 horses	1.1	2.2	9.0
Cutting 8 foot, 4 horses	0.6	2.3	17.5
Cutting, 7 foot, 3 horses	0.7	2.0	14.7
Shocking, 22 bu. yield	1.1	..	9.2
Shock threshing, 22 bu. yield	3.2	3.9	3.1
Barning,[a] 22 bu. yield	3.1	3.0	3.2
Barn threshing, 22 bu. yield	1.9	0.2	5.4

Materials per acre: Seed, 1.9 bu., twine, 2.4 pounds.

[a] Hauling in from shocks and storage in mow.

RYE

The pre-war world production of rye amounted to about one and three-fourths billions of bushels annually or nearly one-half the annual wheat production. At this time Russia produced more than one-half of the world crop of rye, Germany about one-fourth, and Austria-Hungary nearly one-tenth. About 96 per cent of the world's crop of rye was grown and consumed in Europe. During the period 1910 to 1914, the United States produced about 2 per cent of the total rye crop of the world. Production in the United States decreased from 1867 to 1872 and increased slightly from 1873 to 1882, remaining at this figure until about 1912, from which time the increase has been marked.

561. Origin of Rye. Compared to wheat, rye is a relatively new crop. It is not mentioned in old Chinese or Japanese literature and DeCandoll states that it has not been found in Egyptian monuments. The earliest cultivation of rye appears to have been in western Asia and southern Russia.

562. Classification and Types of Rye. Like wheat, rye belongs to the tribe *Hordeae* to the sub-tribe *Triticeae* and to the genus *Secale.* Glumes are one-nerved; 2 and rarely 3 flowers per spikelet. There are 4 groups of varieties of cultivated rye, according to Kornicke:—Common rye, red rye, dark brown rye, and monstrous rye. Monstrous rye[47] is similar to common rye but has more than one spikelet to each internode of the rachis. It is said to have originated in Turkey.

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[46] Falconer, J. I., and Dowler, J. F.—"Variations in Costs of Producing Corn, Wheat, and Other Crops in Greene County, Ohio." *Ohio Agr. Expt. Sta. Bul. 396.* 1926.

Common rye (*Secale cereale*) includes both spring and winter varieties, although the spring rye is only grown in the extreme North and then on a very small scale. One of the more promising varieties of winter rye is Rosen, a variety with large, well-filled heads and large, mostly dark green kernels. This rye was developed at the Michigan Agricultural Experiment Station by selection from a sample sent in from Russia. Dakold rye has small heads, small dark-colored kernels, and rather slender stems. It matures early and is very winter hardy. It was originated by the North Dakota Experiment Station in 1902. Swedish rye (Minn. No. 2) was originated by the Minnesota Agricultural Experiment Station by selection from several plants which did not winter-kill during very severe winter conditions. This selected strain proved higher yielding than other varieties commonly grown in the state. It resembled the Dakold variety somewhat in general appearance. Abruzzes rye was introduced by the United States Department of Agriculture from Italy. It is primarily adapted to the cotton belt, where it makes a rapid and vigorous growth even in cold weather and is valuable for grazing and cover crop purposes. In the Wis. Ped. No. 2 yellow kernels predominate with some mixture of green. It was selected from the Schlanstedt variety introduced into this country from Germany by the United States Department of Agriculture. Mammoth White and Thousandfold are grown somewhat in the northeastern states.

Rye cross pollinates very readily and but few varieties have become well established.

563. Adaptation of Rye. Martin and Smith state that[48] winter rye is the hardiest and earliest of all cereals, though Carleton[49] says that it is not grown as far north nor at such extreme elevations as barley. It is of rare occurrence in very warm regions.

564. The Uses of the Rye Crop.[50] In the South, Abruzzes rye is pastured extensively, due to the fact that it makes a large fall and winter growth when no other crop occupies the land. Rye is the most suitable of the cereals for general use as a pasture crop, yielding considerable fall pasture as well as early spring pasture. It is also valuable as a cover crop to prevent washing of the soil and leaching out of the valuable plant food. Rye is especially valuable as a ~~nurse crop~~ for use in seeding down land to grass and clover; on sandy soil and along the northern limits of the region where wheat can be produced successfully rye is especially desirable as it shades the ground less and for a shorter time, due to its early harvest, than some of the other small grains. It may be used as a soiling crop with good results as it yields well and is ready for use early in the spring when pastures are young and other feeds are generally scarce. Rye straw is valued highly for bedding and packing. By far the largest acreage is cut for the grain.

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[47] Carleton, Mark Alfred—*The Small Grains*, p. 154. The Macmillan Company. New York. 1919.

[48] Martin, John H., and Smith, Ralph W.—"Growing Rye in the Western Half of the United States." *U. S. Dept. Agr. Farmers' Bul. 1358*. 1923.

[49] Carleton, Mark Alfred—*The Small Grains*, p. 153. The Macmillan Company. New York. 1916.

[50] Leighty, C. E.—"The Place of Rye in American Agriculture." *U. S. Dept. Agr. Yearbook 1918*, pp. 177-182.

Most of the rye grain consumed in this country is ground into flour and mixed with wheat flour to make rye bread, though a good portion of the crop is exported. The amount exported from year to year depends largely on the condition of the rye crop in Europe. In general, rye is not considered a suitable concentrated feed for livestock.

565. Recommended Varieties. The varieties recommended by agronomists at the various northern experiment stations include Rosen, Common, Minnesota No. 2, Wisconsin Pedigreed, Dakold, Swedish Advance, and some Abruzzes. In the South, Abruzzes, Common, Italian, Georgia, and Rosen are recommended. Rye varieties are not so numerous as wheat and oats.

566. Date of Seeding. The time of seeding rye depends very much upon the use to be made of the crop. It may be seeded 2 or 3 weeks later than the time of seeding winter wheat as it germinates more quickly and makes a more rapid growth, especially in cool weather. When grown for pasture or as a green manure cover crop it may be seeded as early as August.

Hume *et al.*[51] report an 8-year average of rye seedings made on the 1st and 15th of each month from July 15 to December 1. The average yields for the 8-year seedings were: July 15, 16.8; August 1, 19.1; August 15, 20.5; September 1, 24.4; September 15, 25.3; October 1, 25.0; October 15, 19.6; November 1, 18.1; November 15, 18.2; December 1, 17.3 bushels.

Zook [52] reports the date of seeding test with spring rye as a 7-year average where the first seeding was made as early as possible in the spring and 4 others at intervals thereafter. The first seeding yielded 15.1 bushels; second seeding, 15.4; third, 15.5, and fourth, 10.9.

Hutcheson [53] found that, in Virginia, rye gives the highest yield of grain when seeded at the time most favorable for wheat production.

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[51] Hume, A. N., *et al.*—"The Date of Seeding Winter Rye." *S. Dak. Agr. Expt. Sta. Bul. 220.* 1926.

[52] Zook, L. L.—"Spring Grains." *Nebr. Agr. Expt. Sta. Bul. 213.* 1926.

[53] Hutcheson, T. B.—"Dates of Seeding Winter Grain." *Va. Agr. Expt. Sta. Circ. 3.* 1908.

Rye seeded on September 15 yielded 15.5; on September 30, 18.4; on October 15, 18.5, and on October 30, 16.9 bushels.

Mooers,[54] in Tennessee, found that rye should be seeded about the same time as winter wheat for grain production. If to be used for pasture the seeding should be done somewhat earlier.

567. The Rate to Seed Rye. Moore and Leith [55] state that heavy seedings do not pay and that 1½ bushels per acre is the proper recommended rate under Wisconsin conditions. As a nurse crop on sandy soils they recommend seeding rye at 3 pecks to 1 bushel per acre.

Hume, Champlin, and Morrison [56] report the 2-year average yields for seeding 2, 3, 4, 5, and 6 pecks per acre at the Highmore station (S. D.). Two pecks yielded 14; 3, 14.3; 4, 14.5; 5, 18.1; and 6, 16.9 bushels per acre. At the Cottonwood station seeding at the rate of 3, 4, and 5 pecks produced, as a 2-year average, 4.6, 4.1, and 4.3 bushels, respectively. Swedish rye was the variety used.

Montana [57] reports seeding at the rate of 2, 4, 5, 6, and 8 pecks per acre. As a 4-year general average of experiments carried out at 7 substations the yields were 25, 25.9, 22.4, 27.2, and 25.9 bushels, respectively.

Minnesota [58] reports the effect of seeding Swedish rye at 70, 96, and 112 pounds per acre on the yields of straw and of grain. The yields of grain were 22.42, 20.76, and 20.20 bushels, respectively; the straw yields were 1.66, 1.79, and 1.59 tons, respectively, as a 3-year average.

568. Volunteer Rye. In certain sections of the West after rye has been harvested, the crop volunteers in the stubble and becomes quite a problem to eradicate. In some cases rye is grown for 2 years on the same piece of land and then is fallowed before being put to wheat or other crops.

Martin and Smith [59] state that the chief disadvantage of growing rye is its tendency to volunteer. They state that it is very difficult to eradicate rye in a system of continuous small grain farming, and as appreciable quantities of rye in wheat lowers the market grade and consequently the price, wheat should not be sown on land that produced rye the previous season.

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[54] Mooers, C. A.—"The Small Grains in Tennessee." *Tenn. Agr. Expt. Sta. Bul. 112.* 1915.

[55] Moore, R. A., and Leith, B. D.—"Wisconsin Rye." *Wis. Agr. Expt. Sta. Bul. 326.* 1921.

[56] Hume, A. N., *et al.*—"Winter Grain in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 161.* 1915.

[57] Atkinson, Alfred, and Nelson, J. B.—"Dry Farming Investigations in Montana." *Mont. Agr. Expt. Sta. Bul. 83.* 1911.

[58] Arny, A. C., and McGinnis, F. W.—"Field Crop Variety Trials on the Coon Creek Peat Experimental Fields, 1919-25." *Minn. Agr. Expt. Sta. Bul. 228.* 1926.

[59] Martin, John H., and Smith, Ralph W.—"Growing Rye in the Western Half of the United States." *U. S. Dept. Agr. Farmers' Bul. 1358.* 1923.

STUDY QUESTIONS ON CHAPTER XIX

1. In considering wheat prices in the future, in which countries of the world would you be interested from the standpoint of competition? What particular statistical items about these countries would be helpful in forecasting wheat prices?
2. Point out the limits of possible wheat production in the United States; in the world.
3. In general, is a dry, medium, or wet season more favorable to wheat in your section of the country? Explain.
4. Considering the constituents of the various parts of a wheat kernel, what justification do you see in the use of whole wheat bread?
5. Construct a chart showing (1) the different types of wheat, (2) where grown in the United States, (3) acreage, (4) important varieties and (5) principal uses of each type.
6. What considerations prevent the more general use of Emmer and of Spelt in the United States?
7. With a substantial premium for high protein wheat, what can you do to increase the protein content for your crop?
8. What considerations determine the best date for seeding winter wheat? Spring wheat? When would you seed each of these crops in your section?
9. What considerations determine the rate to seed winter wheat? Spring wheat? At what rate would you seed each of these crops? Why does the rate of seeding vary in different sections and where is it highest and where lowest?
10. Would you drill or broadcast winter wheat? Spring wheat? Justify your decision.
11. What effect does pasturing winter wheat in the fall have upon the yield? What should determine the practice to follow? Will you pasture in your section?
12. If you actually receive a gross return of $26 per acre for corn, $20 per acre for winter wheat, and $16.00 per acre for oats, which crop is the most profitable?
13. Under what conditions will you grow rye? What are the uses of this crop?
14. Make a chart of operations in growing rye showing variety, time, depth, rate, and method of seeding the crop.

APPLICATION ASSIGNMENTS ON CHAPTER XIX

1. A man in the winter wheat belt who grows 320 acres of wheat is given an opportunity to double his acreage for one season. Labor and machinery are available so that his costs per acre will not be increased above normal. He wishes information on wheat at home and abroad. What statistics

will be of the greatest value to him in determining a year in advance the probable price of wheat?

2. You decide to grow 40 acres of wheat on your farm. Select the type and variety you will grow, giving your reasons.
3. You are ready to seed your winter wheat two weeks before the regular time of seeding. What considerations will aid you in deciding whether to seed now or wait? Which will you do? Why?
4. Half of the acreage you are using for winter wheat is average in fertility, the other half is very rich. At what rates will you seed each half? Why? Your winter wheat seedbed dried out on top so that at the normal seeding time there was a four-inch layer of clods on the surface. What will you do? Why?
5. A man offers you one dollar per head, per month, for allowing him to pasture 30 head of cattle on your 40 acres of wheat, which has made a heavy fall and winter growth. Under what conditions would you rent, if at all?
6. You have two fields, one a rather fertile clay, the other a sandy loam somewhat low in fertility. You are considering both winter wheat and rye. What will you do? Why?
7. A field intended for wheat is to be seeded to rye instead. What changes in methods, times, and rate of seeding will you make in handling the rye crop instead of wheat?

CHAPTER XX

OATS AND BARLEY

Of the cereal crops grown in the central corn belt the oat crop ranks second only to corn in acreage and farm value, while for the United States it ranks third. In this country nearly fifty million acres are planted to oats annually, which is about two-thirds of the wheat acreage and less than half the corn acreage. The acreage of barley is only about one-fifth that of oats but is apparently gaining in importance. Oats and barley may be said to be competing crops.

OATS

569. Origin of Oats. The origin of common oats is not definitely known, but it is not believed to be nearly so old as wheat. Carleton[1] states that there is a prevailing opinion at present that two species, *Avena fatua L.* and *Avena sterilis L.*, have given rise to practically all cultivated oats. The *sterilis* species is of more recent origin than the others and is definitely known to be native to northern Africa. The *sativa* species, which is probably derived from *Avena fatua* and includes nearly all the cultivated varieties, appears to have arisen in eastern temperate Europe or western Asia.

570. The Oat Plant. The oat plant bears its seed in a panicle usually 9 to 12 inches long. There are several whorls of branches which rise from the sides of the rachis. The panicle may be either spreading or compacted and turned to one side, as in side oats. Each branch of the head bears from 1 to 8 spikelets, each spikelet containing 2 or more flowers. Only the 2 lower flowers of the spikelets usually develop, though occasionally 3 or even 4 may develop. The glumes are broad, boat-shaped, and rather thin and papery. The lemma is much firmer in texture in the *sativa* and *sterilis* groups and, except in *Avena nuda* the lemma clasps the kernel and the edges of the palea and is usually awned. The lemma and palea together make up the hull of the common oat **(105) (107).**

571. The General Adaptation of Oats. Oats are not grown as far north or at as high an altitude as barley. They correspond more to wheat in this respect. Excepting for the *sterilis* group, oats are somewhat inclined to be a cold climate cereal and are not generally grown in tropical regions. In the United States the great oat producing regions are confined principally to the more humid portions. Seasonal distribution of the precipitation is frequently more of a limiting factor in the production of oats than the total rainfall. In the corn belt the occurrence of hot, dry weather during the ripening period is one of the most common causes of reduced production. (Figure 5.)

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[1] Carleton, Mark Alfred—*The Small Grains*, p. 93. The Macmillan Company. New York. 1916.

The two great centers of oats production are western Europe and the north central portion of the United States. The United States produces slightly more than one-fourth of the total crop of the world and is nearly equaled by Russia. Other countries with a large production are Germany, Canada, France, Austria-Hungary, and the United Kingdom, in the order named. During the period 1909 to 1919 there was a great increase in oat production in the United States and in this period 1,500,000,000 bushels were produced annually, or one-third of the world's crop. (Figure 24.)

Winter oats are only slightly winter hardy, being grown in the Mediterranean region and the southern part of the United States.

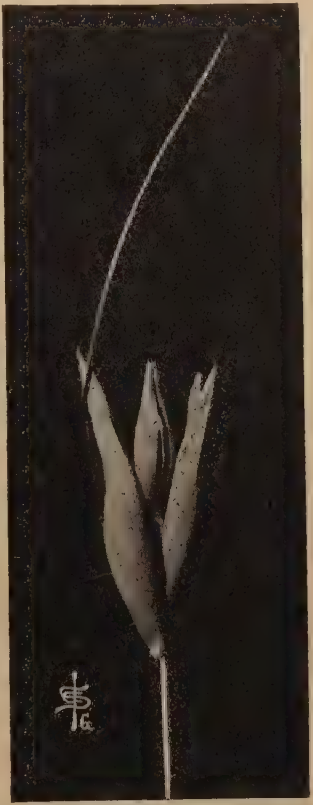

FIG. 109.—Three flowers are usually found in the oat spikelet. The lower one develops into the larger grain, usually referred to as the "bosom oat" and the second flower into the "pin oat." In some cases the third flower also develops as is shown here. The empty outer glumes have been removed.

Warburton[2] recommends winter oats as far north as southern Maryland, central Tennessee, central Arkansas, and southern Oklahoma. He states that they are grown to a limited extent in Utah, Oregon, and Washington.

Salmon[3] states that the January–February isotherms of 20° F. and 30° F. coincide very closely with the northern limits of winter barley and winter oats, respectively.

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[2] Warburton, C. W.—"Winter Oats for the South." *U. S. Dept. Agr. Farmers' Bul. 436*. Rev. ed. 1917.

[3] Salmon, S. C.—"The Relation of Winter Temperature to the Distribution of Winter and Spring Grains in the United States." *Jour. Amer. Soc. Agron.*, Vol. 9, No. 1, p. 23. Jan., 1917.

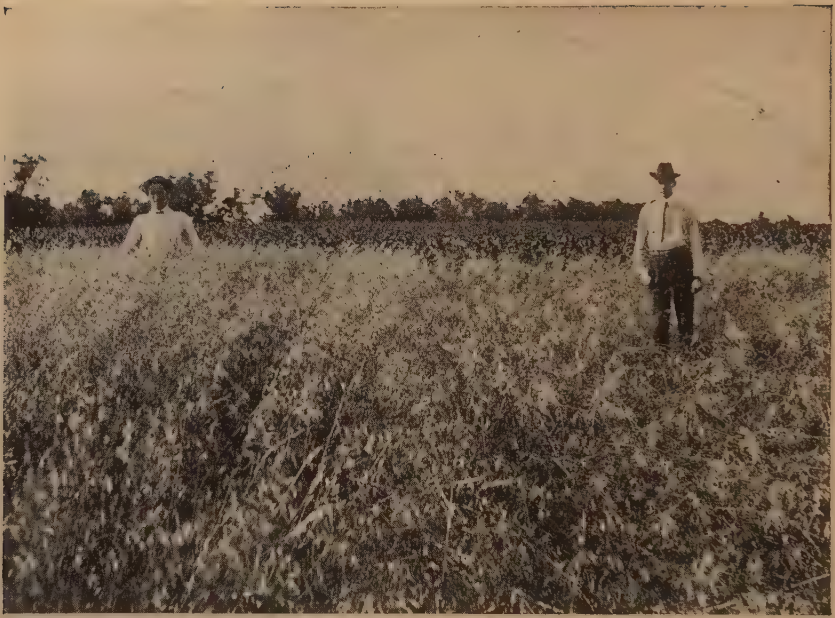

Fig. 110.—Different varieties of oats vary greatly in adaptation and relative yielding ability. At the left is the Iowa 105 variety (also known as Richland) distributed from Iowa Station and recommended particularly for planting on fertile soils where oats are likely to lodge.

572. Classification of Oats. Etheridge[4] has classified oats into 8 more or less distinct groups.

A. Kernel loose within the surrounding hull; lemma and glumes alike in texture *Avena nuda* (hulless oats)

AA. Kernel firmly clasped by the hull; lemma and glumes different in texture

B. Upper grains persistent to their rhachillas *Avena sterilis* (red oats)

BB. Upper grains easily separating from their rhachillas

C. Lemma extended as teeth or awn points

D. Lemma extended with 4 teeth or awn points *Avena abyssinica* (Abyssinian oats)

DD. Lemma with 2 teeth or awn points

E. Lemma elongate, lanceolate, with distinct awn points *Avena strigosa* (rough or sand oats)

EE. Lemma short, abrupt, blunt, rather toothed than awn-pointed. *Avena brevis* (short oats)

CC. Lemma without teeth or awn points

D. Basilar connections of the grains articulate *Avena fatua* (wild oats)

DD. Basilar connections of the grains solidified

E. Panicles roughly equilateral, spreading *Avena sativa* (common or spreading oats)

EE. Panicles unilateral, appressed *Avena sativa orientalis* (side oats)

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[4] Etheridge, W. C.—"A Classification of the Varieties of Cultivated Oats." *N. Y.* [*Cornell*] *Agr. Expt. Sta. Mem. 10*, p. 125. 1916.

The commercial varieties are found in *Avena sativa, Avena sterilis, Avena orientalis,* and *Avena nuda.*

573. Types and Varieties of Oats. Oats are classed as spring or winter according to the time of seeding. Winter oat production is

573a. Varieties generally grown and varieties recommended by the state agricultural experiment stations for the different sections of the United States.

Section	Varieties Grown	Varieties Recommended
New England States and N. Y.	Swed. Sel.; Manchester, Mammoth Cluster, O. A. C. 72	Cornellian; O. A. C. 72
Wis., Minn., Mich..	Swed. Sel.; Wolverine; Worthy; States Pride; Wis. Wonder; Gopher; Minota; W. Russian	Wolverine; Worthy; Gopher; Swed. Sel.
Ia., Mo., Ill., Ind., O., Pa., N. J., Md., Del.	Silvermine; Swed. Sel.; Big 4; 60-Day; Keystone; Peterson; Cornellian; Victory; Miami; Fulghum; Iowar; Iowa 103; Kherson; Iogren; Burt; Richland; Culberson; Mongrel Black	Silvermine; Keystone; Richland; Kherson; Fulghum; Iowar; Burt; Cornellian; Victory; Kanota; Gopher; Iogren; Big 4; Iowa 103 and 105; Miami; Swed. Sel.; 60-Day.
Ky., Tenn., W. Va.	Fulghum; Burt; 60-Day; Grey Turf; Red Rust Proof; Northern White	Fulghum; Burt; Kherson; Iowa 103; Gopher; Va. Grey Turf
Va., N. C., S. C., Ga., Fla.	Swed. Sel.; Burt; Fulghum; Appler; Va. Grey Winter	Fulghum; Culberson; Richland; Keystone; Appler; Welcome
Ark., La., Miss., Ala.	Fulghum; Red Rust Proof; Kherson; Burt; Appler; Bancroft; Patterson; Mcghee; Va. Turf	Fulghum; Appler; Burt; Va. Turf; Patterson; Ferguson; Red Rust Proof
Mont., Ida., N. Dak.	Swed. Sel.; Silvermine; 60-Day; Victory; Siberia; Gr. Russian; Big 4; Kherson; Idamine	Victory; Idamine
Wash., Ore.	Banner; Abundance; Swed. Select	Markton
Neb., Kans., S. Dak.	Burt; Swed. Sel.; 60-Day; Silvermine; Kherson; Neb. 21; Kanota; Red Texas Cole	Cole; 60-Day; Richland; Neb. 21; Kanota
Ariz., Nev., Utah, Col., Wyo.	Swed. Sel.; Col. 37; Great Dakota	Col. 37; Swed. Sel.
Okla., Tex., N. Mex.,	Tex. Red Rust Proof; Tex. Red; Ferguson 71	Tex. Red Rust Proof; Col. 37; Ferguson 71
Cal.	Calif. Red; Fulghum	Fulghum

limited generally to the southeastern portion of the United States, and the great bulk of the oat crop in the United States is spring sown. Often the variety which is grown as a winter oat in the South may be grown as a spring oat in other sections. Oats are often classed as either early or late, depending upon the time required from planting until maturity. The varieties most commonly recommended for various sections of the country by the agronomists of the different states are shown in Table *573a*.

574. Hulless Oats. Hume[5] compared hulless and 3 standard varieties in South Dakota. (One-year test.)

574a. Yield of hulless oats. South Dakota.

VARIETY	YIELD IN BUSHELS PER ACRE (32 lbs. per bu.)	PERCENTAGE OF HULL	YIELD OF FREE GRAIN IN BUSHELS PER ACRE (32 lbs. per bu.)	POUNDS OF PROTEIN PER ACRE IN WHOLE GRAIN (N x 6.25)
Iowa 105	54.6	28.7	38.93	250.02
Sixty-Day	43.7	28.8	38.11	212.28
Fowlds Hulless	23.4	...	23.4	129.17
Swedish Select	39.0	37.2	24.49	176.97

Liberty Hulless, considered one of the most promising of the hulless varieties for the corn belt, has been compared with the better hulled varieties at the Iowa Station[6] with the results shown in Table *574b* as an average of 5 years.

574b. Yield of hulless oats. Iowa.

VARIETY	5-YR. AV. YIELD LBS. PER ACRE	LBS. PER ACRE MINUS HULLS
Iogren	2286	1600
Iowar	2286	1600
Silvermine	2276	1593
Green Russian	2228	1560
Minota	2218	1553
Kanota	2148	1504
Swedish Select	2148	1504
Liberty Hulless	....	1326

575. Uses of Oats. The oat kernel resembles wheat in composition, but contains less carbohydrate and more protein and fat. About 3 per cent of the oat crop of the United States is milled for human consumption. Approximately a third of our total production is sold from the farms where produced. The crop is particularly advised as a horse feed and for young, growing stock, and most of the crop is used for this purpose **(514).**

[5] Hume, A. N.—"Some Tentative Statements concerning a Variety of Hulless Oats." *S. Dak. Agr. Expt. Sta. Bul. 205.* 1924.

[6] Burnett, L. C.—Unpublished Data. *Ia. Agr. Expt. Sta. 1927.*

577a. *Date of seeding as influencing the yield of oats. Summary.*

(Yields in bushels per acre.)

STATE AND REFERENCE	RANGE OF SEEDING DATES	NO. OF YEARS	1st	2nd	3rd	4th	5th	6th	7th	8th
S. Dak. Bul. 227	3/1 -6/1	8	19.9	40.5	42.3	41.8	42.8	38.4	31.3	
Mont. Bul. 84	4/16-6/6	3	98.5	88.1	101.5	86.3	79.4	74.2	55.1	48.1
Mont. Bul. 84 (Straw, tons)	4/16-6/6	3	1.92	1.73	1.92	2.43	2.22	2.08	2.32	2.46
Ohio Bul. 257	3/30-5/10	3	57.2	58.5	55.9	53.9	48.8	...	...	...
Ohio, 2nd test	3/22-5/8	3	69.1	64.1	55.6	50.7	...	...	...	...
Ohio, sep. straw (lbs.)	3/22-5/8	3	2905	2209	2722	2839	...	...	...	...
Ohio (sep. wt. per bu.)	3/22-5/8	3	30.5	28.4	27.6	27.1	...	...	...	...
Kans. Bul. 74	3/1 -4/20	5	24.5	31.1	26.9	22.7	21.1	15.0	12.5	12.7
Nebr. Bul. 213	3/25-4/29	17	29.1	30.9	26.5	22.7	...	...	...	...
Ill. Bul. 41	3/22-5/4	2	42.8	46.8	47.0	42.3	35.9	30.2	27.7	...
Can. Bul. 37 [a]	4/20-5/30	13	67.2	69.8	69.9	65.7	63.4	...	...	...
Can. Rpt. [b]	4/16-5/21	2	57.0	59.0	58.0	56.0	49.0	...	...	...
Nebr. Bul. 201	3/21-4/20	7	58.2	49.4	38.6	...	...	...	...	...
Mo. Bul. 229	3/15-4/15	3	52.7	43.4	28.8	(Fulghum)				
Mo. Bul. 229	3/15-4/15	3	44.5	31.8	26.2	(Silvermine)				
Mo. Bul. 229	3/15-4/15	3	40.9	38.5	34.4	(Kherson)				
Mo. Bul. 229	3/15-4/15	3	30.0	23.1	20.1	(Swedish Select)				
Can. Bul. 332 [c]	4/14-5/20	5	71.2	67.6	64.0	59.1	51.9	36.2	O. A. C.	No. 72
Can. Bul. 332	4/14-5/20	5	66.5	67.2	66.7	66.8	61.8	47.0	O. A. C.	No. 3

[a] *Canada Expt. Farms, Seasonable Hints, Prairie Ed. No. 37.* Mar., 1927.

[b] *Canada Expt. Farms, Rosthern (Sask.) Sta. Rpt. Supt.,* p. 20. 1925.

[c] *Ontario Agr. Expt. Sta. Bul. 332.*

576. Culture of Oats. The preparation of the seedbed for oats differs from that of many other crops in that the land is seldom plowed when oats follow a cultivated crop. Usually the land is not in condition in the spring so that it could be plowed and still get the oats seeded sufficiently early to secure satisfactory yields. Data bearing on the preparation of the oat seedbed are contained in Chapter X.

577. Time of Seeding Oats. The recommendation is usually made that oats be seeded as soon as possible in the spring after the land can be worked. In the comparisons reported from the different stations the earliest seedings usually have been made as soon as the ground could be put in shape for seeding.

Montana[7] reports that for oats, the average yields were reduced by a little more than 2 per cent for each day's delay in seeding after the period between April 29 and May 16.

Duggar[8] reports that, as a 7-year average in Alabama, red oats sown in November averaged 11.3 bushels more per acre than when sown in February. October was advised for fall sowing and the first few days in February for spring sowing in Alabama.

At the Arkansas Experiment Station[9] red oats were seeded from September to the second week in November. As an 8-year average, when the yield of seedings which were made the first week in October is taken as 100, the yields, starting from the second week in September, by weekly periods were: 117, 101, 112, 100, 84, 62, 40, 10, and 10.

Mooers[10] reports that as an average for an 8-year period, seeding winter oats September 1 to 15, September 16 to 30, October 1 to 15, October 16 to 31, and November 1 to 7, the grain yields were 46.8, 48.0, 42.8, 40.5, and 24.5 bushels per acre, respectively.

McClelland[11] found that winter oats seeded on the poorer soils in October yielded 50 per cent more than November plantings, but that on very rich soils there was little difference betwen September and October plantings.

578. Rate of Seeding. The most satisfactory rate of seeding may depend upon the variety, the rainfall, the soil, or other factors. Yields in bushels per acre reported from a number of stations for different rates of seeding are shown in Table *578a.*

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[7] Linfield, F. B.—"Some New Facts from the Montana Experiment Station." *Mont. Agr. Expt. Sta. Ann. Rpt. 32*, p. 42. 1925.

[8] Duggar, J. F.—"Experiments with Oats." *Ala. Agr. Expt. Sta. Bul. 137.* 1906.

[9] Nelson, Martin, and Osborn, L. W.—"Report of Oats Experiments, 1908-1919." *Ark. Agr. Expt. Sta. Bul. 165.* 1920.

[10] Mooers, C. A.—"The Oat Crop." *Tenn. Agr. Expt. Sta. Bul. 136.* 1926.

[11] McClelland, C. K.—"Winter Crops." *Ga. Agr. Expt. Sta. Bul. 117.* 1915.

578a. *Rate of seeding (pecks per acre) as influencing the yield of oats. Summary.*

STATION	No. of Years	2	4	6	8	10	12	14	16	18
Nebr. Bul. 160										
Kherson, all tests	8–12	....	47.0	....	55.1	59.1	59.4	....	55.6	....
Kherson [a]	4	....	54.4	....	54.7	57.7	57.6	57.7	58.9	....
Swedish Select [a]	4	....	32.4	....	36.6	38.2	39.8	39.8	38.6	....
Nebr. Bul. 193	15	24.6	29.6	33.5	31.9	....	....	....	....	....
Ill. Bul. 41	6	....	42.2	44.5	48.9	52.8	52.2	51.9	51.4	....
Kans. Bul. 74	7	....	24.65	27.87	29.12	30.86	30.43	30.43	32.79	....
Ohio Bul. 257a	9	....	49.94	52.97	53.43	53.54	52.64	....	....	....
Mo. Cir. 105	3	....	18.9	20.9	22.0	22.4	23.9	....	....	....
Miss. Bul. 171 (winter oats)	1	....	....	25.0	34.0	35.0	38.0	....	....	....
Ia. Bul. 175	5									
Silvermine		....	....	....	45.82	46.68	52.04	51.30	52.32	51.78
Kherson		....	....	....	51.90	53.60	55.48	56.64	57.96	58.14
Iowa 105		....	....	....	68.70	67.80	70.10	70.52	68.80	66.46
U. S. D. A. Bul. 1039										
(Belle Fourche, S. D.)	6	....	39.8	40.6	37.9	37.2	(Dryland)			
(Belle Fourche, S. D.)	2	....	....	67.8	70.8	68.9	66.5	(Irr.)		
N. Y. Bul. 346										
Small seeded variety		....	....	55.2	....	58.5	55.9	....	59.0	....
Medium seeded variety		....	....	44.0	....	51.5	48.7	....	53.2	....
Large seeded variety		....	....	32.0	....	36.7	39.3	....	40.9	....
Mont. Bul. 120 (Irrigated)	8	75.83	90.34	94.75	95.73	103.77	106.44	106.27	102.68	....
Ind. Bul. 225 (2 varieties)	7	....	....	46.9	50.7	50.7	51.6	....	49.3	50.4 [d]
Ark. Bul. 165	6	....	....	34.4	41.4	42.7	43.5	39.5	....	....
Mich. Spec. Bul. 116	3	....	....	....	88.0	101.0	100.0	103.0	83.0	85.0
W. Va. Bul. 200	4	....	....	27.0	29.7	30.6	31.2	....	....	....
Canada 1925 [a b]	2	39.1	40.3	39.7	43.2	45.4	42.6	....	....	....
Neb. Bul. 201	10									
Kherson		....	51.1	51.8	54.0	55.9	56.2	55.9	55.4	....
Swedish Select [c]		....	37.1	44.6	43.6	45.3	46.7	46.3	46.1	....
Tenn. Bul. 136 (Winter)	9	48.9	51.2	49.1	50.4	46.3	49.1	....	....	....

[a] It is specifically stated that the weight of the seed has been deducted from the yields given.

[b] *Canada Expt. Farms, Rosthern (Sask.) Sta. Supt. Rpt.* 1925.

[c] The 6-pk. rate was used only 6 years.

[d] 20 pecks seeded.

579. Methods of Seeding Oats. Oats are either drilled or sown broadcast. For broadcast seedings, the use of the end-gate seeder is a popular method. Other broadcasters are common and in certain sections seeding is done by hand. Less seed is ordinarily planted per acre where the drill is used, as the drill distributes the seed more evenly on the ground and covers it to a uniform depth so that more of the seed make plants. However, a good many of the farmers in the corn belt who have drills do not use them in seeding oats, believing that factors other than the method of seeding have a greater influence on yield (Figure 62).

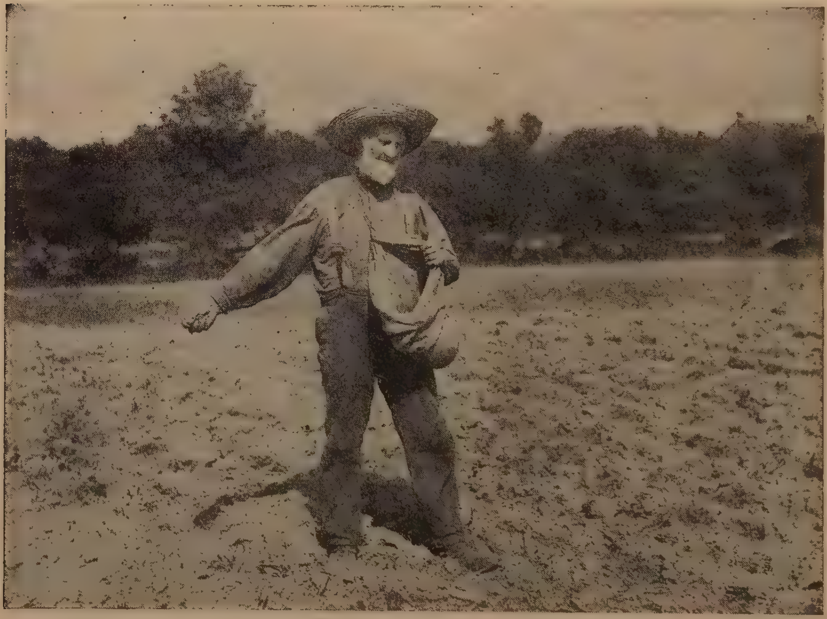

FIG. 111.—A method of seeding oats which was once common. *The different experiment stations report an increase of several bushels per acre from drilling oats as compared with the yield from broadcasting; yet in the states where oats are grown most extensively, broadcasting is the common method. Account for this.*

It is usually possible to plant earlier when the seed is broadcast than when the seedbed must be prepared for drilling and the yields obtained from drilling and broadcasting should be interpreted in the light of the information gained by time of seeding experiments. If early seeding in a particular section is advantageous, it is possible that oats can better be broadcast than drilled in spite of the larger yield obtained from drilling when both seedings are made at the same date.

The results of comparative seedings at a number of the experiment stations are summarized in Table *579a.*

579a. Drilling vs. broadcasting oats as influencing yield of grain. Summary.

Station	Duration Years	Bushels per Acre	
		Drill	Broadcast
Wis. Bul. 339	7	57.1	61.5
Ill. Bul. 136			
Urbana field	3	40.8	35.6
DeKalb field	3	32.1	29.8
Sibley field	2	33.3	29.7
Iowa Bul. 175	9	54.7	49.7
Nebr. Bul. 193	9	32.4	25.9
Kans. Bul. 74	7	28.34	26.24
Neb. Bul. 160	4	57.9	58.8
Miss. Bul. 171	2	35.2	22.8
Ala. Bul. 173	4	34.7	33.6
Ontario Bul. 332	5	53.4	50.8
Ark. Bul. 165	4	37.2	27.1
Ind. Bul. 14	2	43.5	42.8

580. Depth of Seeding Oats. Several stations have reported yields of oats seeded at different depths.

580a. Depth of seeding oats as influencing yield; bushels per acre. Summary.

Station and Bulletin No.	Depth of Seeding—Inches					
	1	2	3	4	5	6
Ill. Bul. 41—6-yr. av. relative yield	90.0	84.0	73.0	78.0	45.0	31.0
Ky. Bul. 23	26.2	39.8	31.2	...	...	...
Ohio Bul. 138—10-yr. av.	56.0	52.5	48.3	48.3	...	...

581. Proportion of Grain to Straw. Love[12] found that certain strains of oats produced almost a pound of grain to each pound of straw, while others required nearly 2 pounds of straw to produce 1 pound of grain. The proportion of grain to straw varies greatly in different soils and with different climatic conditions.

Musgrave[13] found that in New Jersey there was a general association of large grain yields with low straw yields in the case of oats. Kherson oats produced 358.5 grams of grain to 415.5 grams of straw, while the Crown variety produced 181.5 grams of grain to 774.33 grams of straw.

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[12] Love, H. H.—"Relation of Yield of Straw and Grain in Oats." *Jour. Amer. Soc. Agron.* Vol. 6, No. 3, p. 108. May-June, 1914.

[13] Musgrave, George W.—"Correlation of Yield of Straw and Grain in Oats in New Jersey." *Jour. Amer. Soc. Agron.* Vol. 17, No. 12, pp. 774-775. Dec., 1925.

582. Labor Requirement in Oat Production Operations. The labor requirements for the various operations in producing a crop of oats are very similar to those for wheat (560). The man and horse labor required per acre for various operations as reported by the Ohio [14] station are as shown in Table *582a*.

582a. Labor required in oat production. Ohio.

OPERATION AND IMPLEMENT USED	LABOR PER ACRE		ACRES COVERED IN 10-HOUR DAY
	Man Hours	Horse Hours	
Disking, 7-foot, 4 horses	0 7	3.0	13.5
Drilling, 7-foot, 3 horses	.8	2.4	12.5
Broadcasting, 36-foot, 2 horses	.3	.5	40.0
Cutting, 8-foot, 4 horses	.6	2.4	16.6
Cutting, 7-foot, 3 horses	.7	2.1	13.8
Shocking, 40 bu. yield	1.1	..	9.5
Shock threshing, 40 bu. yield	2.9	3.4	3.5

Materials per acre:
Seed, drilled, 2.6 bushels
Seed, broadcasted, 2.9 bushels
Twine, 2.3 pounds

BARLEY

Barley ranks fourth in importance among the cereal crops of the United States, being exceeded in value by corn, wheat, and oats. Russia formerly produced over one-fourth of the world's crop of 1,400,000,000 bushels and probably has continued to produce as much. Barley is extensively cultivated in northern India, central Europe, Spain, north Africa, and Japan. The percentage of the crop land in barley is highest in Algeria and Japan (Figure 23).

583. Origin of Barley. Barley is one of the most ancient of the cultivated plants. Carleton [15] states that the oldest barley ancestor now known occurs in the region of the Red and Caspian seas and the Caucasus mountains. It resembles the two-row barley, although Carleton states that the six-row barley seems to be the species most anciently cultivated.

584. Adaptation of Barley. Spring barleys attain the widest latitude and the highest altitude of all cereals. Winter varieties, on the other hand, are not particularly hardy, being less hardy than winter wheat but a little more hardy than winter oats. Barley is better adapted to alkali soils than other cereals **(183)**.

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[14] Falconer, J. I., and Dowler, J. F.—"Variations in Costs of Producing Corn, Wheat, and Other Crops in Greene County, Ohio." *Ohio Agr. Expt. Sta. Bul. 396*, p. 263. 1926.

[15] Carleton, Mark Alfred—*The Small Grains*, pp. 122-124. The Macmillan Company. New York. 1916.

In general, the barley plant is adapted to regions of cool summers where the soil is not too sandy but well drained. It does not do well on poorly drained soil nor under humid conditions where high temperatures prevail.

Under semiarid conditions in tropical sections, it does well where sufficient water is available for growth.

FIG. 112.—Barley is one of the most ancient of our cultivated plants. The method of harvesting shown here still prevails in parts of southwestern Asia in the region where the plant probably first was cultivated.

585. Uses of Barley. Ball *et al.*[16] state that the larger part of the barley crop of the United States has always been marketed in competition with oats and corn as a feed grain, but that before prohibition 30 per cent, or approximately 50,000,000 bushels annually, was used for brewing. The prohibition regulation has not had the effect on the barley market which many anticipated. Barley is generally considered about 90 to 95 per cent as valuable as corn for fattening livestock. When crushed or rolled, it is a good feed for all kinds of stock. In addition to its use for feed and malting, barley is used in combination in the making of breakfast food preparations and flour, in the form of pearl barley for thickening soups and for other purposes, and as ground barley **(514)**.

586. Classification of Barley. Barley belongs with wheat and rye in the same tribe of grasses, *Hordeae*. It differs from the other

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[16] Ball, C. R., *et al.*—"Oats, Barley, Rye, Rice, Grain Sorghums, Seed Flax, and Buckwheat." *U. S. Dept. Agr. Yearbook 1922*, p. 492.

2 in having 3 spikelets at each joint of the rachis, 2 of which are sterile or rudimentary in many types.

Wiggans[17] has classified the barleys showing the relationships and differences between the species.

A. Rhachis articulate
    Hordeum spontaneum (two-row wild barley)
AA. Rhachis non-articulate
  B. All spikelets fertile
    C. Lemmas of all spikelets awned or hooded, kernels of all spikelets equal or nearly equal in size
      Hordeum vulgare (six-row barley)
    CC. Lemmas of central spikelets awned or hooded, lemmas of lateral spikelets bearing neither awns nor hoods, kernels of lateral spikelets much reduced in size
      (x) *Hordeum intermedium*[a] (six-row barley)
  BB. Only the central spikelets fertile
    C. Lateral spikelets possessing non-functional rudimentary sexual organs
      Hordeum distichon (two-row barley)
    CC. Lateral spikelets much reduced in structural parts and possessing no rudimentary sexual organs
      Hordeum deficiens (two-row barley)

[a] The (x) before *H. intermedium* indicates the hybrid origin of this species, also that it is not of equal rank with the other species.

The two commercially important species in the United States are *Hordeum vulgare* and *Hordeum distichon*, although *Hordeum intermedium* is also grown to some extent. There are both winter and spring forms of barley; also bearded, hooded, and beardless barleys. In common barley the awns are barbed; that is, have tooth-like projections on the sides. Others are smooth-awned as in the case of the Velvet and Glabron varieties developed at the Minnesota station. In color barley may be white or yellow, blue, purple, or black. In ordinary barley the kernel and hull are grown together to constitute the grain. In the hull-less barley the kernel separates from the lemma and palea in threshing.

587. Varieties of Barley Recommended. The number of varieties of barley grown extensively and recommended in the different states is not large. Varieties recommended in North and South Dakota are Manchuria, Hannchen, Odessa and White Smyrna; in Iowa and Nebraska and in the states north and east to the Atlantic coast, Manchuria, Oderbrucker, and Wisconsin Pedigreed; from Missouri, east and south, where barley is not so extensively grown as further North the Tennessee winter, Union winter, Virginia hooded, Tennessee No. 6 and Arlington awnless are the chief varieties; in the Rocky Mountain states, Trebi, Coast, Colsess, Horn and Hannchen; in the Pacific Coast states, White winter, Beldi, Horsford, Trebi, Mariout and Coast.

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[17] Wiggans, Roy Glen—"A Classification of the Cultivated Varieties of Barley." *New York [Cornell] Agr. Expt. Sta. Mem. 46*, p. 413. 1921.

Smooth awned varieties have recently been put out by a number of different stations and the acreage of these is increasing rapidly. The Velvet and Glabron from the Minnesota station and the Sparton from the Michigan station are some of the better known varieties. These seem to give fully as large yields as the varieties previously available.

588. Culture of Barley. The common impression prevails that barley requires a better prepared seedbed than oats. This impression perhaps developed during the time that barley was being grown rather extensively for malting purposes and when a uniform maturity and resultant uniformity in germination were considered very desirable. The opinion also prevailed, and for the same reason, that it was quite essential to drill the barley crop rather than to broadcast it. The preparation of the seedbed for barley has been indicated (289).

589. Methods of Seeding Barley. Barley is either drilled or broadcast. Experimental results are given comparing drilling and broadcasting of barley. Time of seeding should be considered, as under certain conditions it is associated with method.

589a. Drilling vs. broadcasting as affecting the yield of barley; yields in bushels per acre. Summary.

STATION AND BULLETIN NO.	NO. OF YEARS	AVERAGE YIELD	
		Drilled	Broadcast
Wis. Bul. 339	7	45.6	46.0
Nebr. Bul. 193	10	23.3	16.2
Nebr. Bul. 160	4	16.5	9.2
Iowa Cir. 48	5	28.4	25.4
Calif. Bul. 211	[a]	70.8	64.4
Ontario Bul. 332	5	36.0	34.7

[a] 22 trials were made over a period of 5 years. This is average.

Champlin *et al.*[18] report drilling barley in rows 6 inches apart; in rows 12 inches apart; in double rows 6 inches apart and 36 inches between pairs of rows, and in triple rows 6 inches apart and 30 inches between the 3 rows. As a 5-year average the yields were 24.4, 22.5, 19.6, and 23.1 bushels per acre, respectively.

590. Depth of Seeding Barley. Harlan[19] states that in humid regions barley should be seeded about 1½ inches deep, in the Northern Plains about 2 inches deep, and in the Great Basin 2½ to 3 inches deep.

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[18] Champlin, Manley, Morrison, J. D., and Martin, John—"Barley Culture in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 183.* 1919.

[19] Harlan, Harry V.—"Cultivation and Utilization of Barley." *U. S. Dept. Agr. Farmers' Bul. 968.* 1918.

The Minnesota station[20] reports seeding barley at different depths, from ½ inch to 3 inches, with the highest yield both of grain and of straw from 1 to 2-inch seedings.

The South Dakota[21] station has reported the results of seeding barley at Highmore from 1½ to 4 inches deep. Two varieties were used and the comparisons were continued through 3 years. The largest yield was secured from seeding 2 inches deep.

591. Time of Seeding Barley. The rather common practice, where both barley and oats are grown, is to seed the oats first and then the barley, as a delay in seeding the barley crop has been considered less injurious than a like delay in seeding oats. A number of stations have made comparisons of barley seedings made at different dates and the results are presented for a number of the stations in Table *591a* on page 485.

Matthews reports[22] work continued through 13 years at the Dominion experimental farm at Ottawa, in which seedings of barley, oats and spring wheat were made at weekly intervals, beginning as soon as it was possible to get onto the land.

591b. Relative influence of date of seeding barley, oats, and wheat on summer fallow; yields bushels per acre, average of 13 years. Canada.

SEEDING AT WEEKLY INTERVALS	YIELDS PER ACRE		
	Barley	Oats	Spring Wheat
First	27.6	67.2	24.9
Second	26.1	69.8	27.9
Third	27.4	69.9	24.4
Fourth	25.6	65.7	24.7
Fifth	28.2	63.4	23.3

The Montana station[23] reports that the yield of barley was decreased 1.5 per cent for each day seeding was delayed after the period from April 29 and May 16.

Mooers[24] reports that, as a 6-year average, winter barley seeded September 17 to 29 produced 50.9 bushels; that seeded October 3 to 7 produced 47.9 bushels; and that seeded October 14 yielded 38.2 bushels per acre.

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[20] Boss, A.—"Field Experiments in 1893." *Minn. Agr. Expt. Sta. Bul. 31.* 1893.

[21] Champlin, M., *et al.*—"Barley Cultivation in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 183.* 1917.

[22] Matthews, V.—"Correlation of Time of Seeding and Yields of Spring Grain." *Canada Expt. Farms, Seasonable Hints, Prairie Ed. 37.* Mar., 1927.

[23] Linfield, L. B.—"Some New Facts from the Montana Experiment Station." *Mont. Agr. Expt. Sta. Ann. Rpt. 32,* p. 42. 1925.

[24] Mooers, C. A.—"The Small Grains in Tennessee." *Tenn. Agr. Expt. Sta. Bul. 112.* 1915.

591a. *Time of seeding barley as influencing the yield of grain; bushels per acre. Summary.*

REFERENCE	RANGE IN DATES OF SEEDING	NO. OF YEARS	SEEDING							
			1	2	3	4	5	6	7	8
Mont. Bul. 84	4/16-6/6	3	70.4	69.5	67.9	59.5	57.2	52.1	41.5	33.5
Nebr. Bul. 193	3/25-4/30	13	23.4	21.7	19.3	14.5				
Kans. Bul. 144	3/14-5/12	1	21.2	25.7	16.9	24.8	7.9	14.6	6.6	
Kans. Bul. 144	2/1 -5/11	1	36.5	30.2	18.5	18.8	11.3	18.3	5.8	
S. D. Bul. 183 (Brookings)	4/20-5/20	3	60.0	46.2	36.8	(*Manchuria*)				
S. D. Bul. 183 (Highmore)	4/1 -5/15	3	51.4	62.4	50.0	(*Odessa*)				
S. D. Bul. 183 (Highmore)	4/1 -5/7	3	52.8	54.8	50.7	(*Gatami*)				
S. D. Bul. 183 (Highmore)	4/1 -5/7	3	61.9	60.8	40.6	(*Hannchen*)				
S. D. Bul. 183 (Highmore)	4/1 -5/7	3	53.5	47.9	42.3	(*White Smyrna*)				
Nebr. Bul. 213	3/25-4/29	17	22.5	23.9	18.9	14.6				
Canada [a]	4/20-5/20	13	27.6	26.1	27.4	25.6	28.2			
Canada [b]	4/16-5/21	2	35.0	36.0	39.0	35.0	32.0			

[a] *Canada Expt. Farms Seasonable Hints, Prairie Ed. 37.* Mar., 1927.
[b] *Canada Expt. Farms, Rosthern (Sask.) Sta. Supt. Rpt.* 1925.

California[25] reports planting barley extremely early, September 18; early, November 6; midseason, January 8; and late, March 22. The yields were 60.0, 80.3, 81.5, and 31.1 bushels per acre, respectively. The variety used was the Mariout.

592. Rate of Seeding Barley. Experiments at a number of stations have been made comparing different rates of seeding barley. The rates per acre have varied from 2 to 16 pecks per acre.

592a. Rate of seeding barley as affecting the yield of grain; yields in bushels per acre. Summary.

Reference	No. of Years	Pecks per Acre						
		4	6	8	10	12	14	16
Iowa Cir. 48	4	25.1	26.3	28.6	26.2	25.6		
Nebr. Bul. 193	11	21.9	22.4	22.9				
Kans. Bul. 144	1	43.1	47.5	47.1	49.2			
U. S. Dept. Agr. Bul. 1039								
Belle Fourche, S. D.	3	21.4	20.5	20.0	18.5			
Mont. Bul. 120	8	64.0	68.9	69.1	72.0	72.7	72.8	76.7
S. D. Bul. 183								
Brookings[a]	3	38.9	41.9	42.1				
Brookings[b]	3	64.5	64.2	62.1	64.2			
Eureka[c]	5	27.3	27.0	25.2				
Highmore[a]	5	40.3	42.4	41.9				
Highmore[c]	4	41.5	43.9	45.5				
Mich. Spec. Bul. 116	3		33.0	38.0	41.0	38.5	41.0	
Ontario Bul. 332	4		48.5	50.3	47.9			

[a] Odessa. [b] Manchuria. [c] Hannchen.

STUDY QUESTIONS ON CHAPTER XX

1. What are the factors which determine the limits of the oat belt?
2. What type and variety of oats do you recommend as best for your section? Why?
3. Why are hull-less oats not grown more extensively?
4. Why are oats so widely grown in the corn belt? Outline the utilization or disposition of the oat crop of the United States.
5. When would you seed oats? What causes variations in the time of seeding in different sections?
6. What rate of seeding gives the best results in your section? What difficulties result from thicker seeding? Thinner seeding?
7. It is reported that in some sections many men owning drills broadcast their oats. Why?
8. When do you recommend that oats to be cut with the binder should be harvested? Why? Explain why oats can be cut at a later time with the combine without lowering the yield.

[25] Hendry, G. W.—"Mariout Barley, Calif." *Agr. Expt. Sta. Bul. 312.* 1919.

9. Compare the labor requirement of a crop of oats and of wheat.
10. Explain the relatively low acreage of barley in your section. In the United States.
11. Farming in your section, you want to produce as much feed per acre as possible. Will you get the greatest return from oats at 40 bushels per acre or barley at 30 bushels?
12. Compare the climate and soil adaptation of barley, wheat, and oats.
13. How is it recommended that barley be fed in order to get the greatest value from the crop?
14. What type and variety of barley would you recommend for your section?
15. Give instructions for the preparing of the barley seedbed, time, rate and method of planting.
16. Why do farmers growing both oats and barley usually seed the oats first?

APPLICATION ASSIGNMENTS ON CHAPTER XX

1. You operate a general farm in the central corn belt and are growing 30 acres of oats. Explain why you grow this crop.
2. You wish to seed 30 acres of oats and have no drill. Will you buy a drill? Why?
3. About one-half of your oat crop is to be planted in a very rich soil and the rest on a soil low in fertility. What variety or varieties will you use? Will you vary the rate of seeding on the two soils? Why?
4. You have a drill but owing to wet weather its use will make your seeding a week later than if you broadcast. What will you do? Why?
5. Your oats, in which alfalfa is seeded, are rank and at the time they are in the milk stage they are blown down. It has been suggested that you harvest the crop for hay. What will you do? Why?
6. You feed a large number of hogs. Your supply of corn is running low. Assuming this, you plan to feed your small grain crop as soon as available. What grain will you seed? Why?
7. You are intending to seed 20 acres of barley and have no drill. Will you buy one? Explain.
8. Your barley is not suited for seed and you want to get a barley that will do well on your farm. What variety will you grow? You can get the seed either from 100 miles north or south. Which will you use? Why?
9. You are asked to speak to a meeting of farmers in your locality, giving a comparison of barley and oats. Write your speech.

CHAPTER XXI

FLAX, BUCKWHEAT, AND RICE

FLAX

Flax, grown for seed, is a grain crop, although it is not classed as one of the cereals. Of the grain crops, flax ranks about seventh in acreage and eighth in value in the United States. We grow approximately a million and a third acres of flax each year. Four states,—North Dakota, Minnesota, South Dakota, and Montana,—produce 95 per cent of the total crop. This is the hard red spring wheat section of the country, also. About 15,000,000 bushels of flax is imported each year, largely from Argentina and Canada. Previous to the World War, Argentina was the greatest flax producing country with India, Russia, the United States, and Canada ranking in the order named (Figure 26).

593. History and Origin. Common cultivated flax is supposed to be native to southeastern Europe and western Asia, and has been cultivated since the dawn of history. It was introduced and grown in America soon after the landing of the Pilgrims in 1620.

594. Types and Varieties. Botanically, flax is known as *Linum* and belongs to the family *Linaceae*. There are, in general, 4 types of flax grown in this country,—textile fiber flax, short fiber flax, European seed flax, and Argentine seed flax.

Dillman[1] states that the textile fiber flaxes are not grown for seed, although the seed is a by-product when the plant is grown for fiber. This is the only type which produces fiber suitable for spinning. The short fiber varieties have been derived from the fiber flax type and are grown for the seed. They make a more slender growth than the so-called Russian or European seed flax, have fewer basal branches, have a more compact panicle, and are generally earlier than the seed flax. The bolls and seed are smaller than those of the seed flax. Among the varieties of this group, the North Dakota Resistant No. 114 is perhaps the best known; while the Chippewa and Winona, distributed from the Minnesota Agricultural Experiment Station, are also superior varieties.

The European varieties of seed flax have stouter stems, more basal branches, larger and more uneven panicles, and larger bolls and seeds than the short fiber type. Among the varieties of this group are North Dakota No. 155, Damont, Reserve, and North Dakota Resistant Nos. 52 and 73. The Argentine flax is not well adapted to the flax producing area of the United States.

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[1] Dillman, A. C. "Production of Seed Flax." *U. S. Dept. Agr. Farmers' Bul. 1328.* 1924.

595. The Flax Plant. The plant is an annual growing from 1 to 3 feet in height, It has a single tap root, with fibrous branches distributed throughout the surface of the soil. The stems of seed flax have 2 or more basal branches and numerous small branches toward the top.

Fiber flax, which is seeded thickly, generally grows with a single, erect stem. The flowers, which are usually self-pollinated, range in color from white to deep blue, with all the flowers on one plant of the same color. The 5 petals, which are large and showy, drop within a few hours after the flower opens. The seed, which are dicotyledenous and oily, are borne in bolls, consisting of 5 chambers, which when completely filled contain 10 seed. They are light brown, yellowish, or in some varieties creamy white in color. The outer covering of the seed contains a mucilaginous material, which quickly becomes sticky when wet.

The flax stem consists of 2 main parts, the central woody core lined with pith and the cortex or bark, which completely encircles the wooden core. Fiber bundles are located in the cortex; and since they form a part of the fibrovascular system of the plant, many of them run nearly the full length of the stem. The fibers of the branches are of practically no value for spinning and therefore a heavy seeding is made as this tends to prevent the development of branches.

596. Uses of the Crop. Seed flax is grown almost entirely as a cash crop, being sold for oil extraction. The two chief products of flaxseed are linseed oil and linseed meal. Linseed oil is used in the manufacture of paints and varnishes, in linoleums, oilcloth, printers' ink, patent leather, imitation leather, and many other products. After the oil has been extracted, the residue is known as linseed cake or, if ground, linseed meal. This is a valuable feed for livestock, especially for dairy cows and for young, growing animals. Flax-seed yields from 30 to 40 per cent of its weight in oil or about 2½ gallons (7½ pounds per gallon) to a bushel of 56 pounds of seed.

Most growers consider flax straw, after threshing, of fair value for feed, usually rating it somewhere near oat straw.

597. Adaptation and Seedbed Preparation. Ball *et al.*[2] state that seed flax has held a unique position in the agriculture of the

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[2] Ball, C. R., *et al.*—"Oats, Barley, Rye, Rice, Grain Sorghums, Seed Flax, and Buckwheat." *U. S. Dept. Agr. Yearbook 1922*, pp. 538-542.

United States as a "first crop" on breaking or newly turned virgin sod. The area of flax production, therefore, has moved westward with the settlement of new land until it has now reached about the western limit of its migration.

In early years of its development it was considered hard on the soil, because it did not produce well if grown continuously on the same field. The later discovery of flax wilt probably accounts for the idea that flax was hard on the land, as it was found that this disease became more and more destructive when flax was grown for several years on the same piece of land. The fact is now well established that a crop of flax is no more exhaustive on the soil than other crops which may be included in the rotation. Flax is particularly well adapted to freshly turned sod, as under such conditions it makes a better growth than most other farm crops. Flax does best on loam or clay soils which are fertile and retentive of moisture. Abundant moisture during the growing period with dry weather during the ripening and harvesting period are most favorable.

A firm seedbed is essential for flax production. For this reason corn ground is usually disked instead of being plowed in preparation for flax. If plowing is necessary, the land should be made firm by rolling or by disking with the disk set nearly straight and harrowing afterward.

Flax does not shade the ground very heavily and, therefore, does not compete with weeds as well as the other cereal crops. Weeds are sometimes a serious problem in flax fields. Its lack of shading and crowding makes the crop excellent as a nurse crop with which to seed clover and alfalfa.

598. Varieties of Flax. Flax varieties recommended by the different stations include N. D. Resistant 114, Winona, Chippewa, N. D. Resistant 52, Linota, White or Blue Blossom Dutch, Saginaw, Reserve, C. I. No. 19 and C. I. No. 205. In determining upon the best variety to seed use should be made of reports covering comparisons in the locality where the seeding is to be made.

599. Time of Seeding. Dillman states that early sown seed usually produces the highest yields. Early sown flax is not easily injured by frost and will stand a temperature of 25° F. in the spring and a still lower temperature after the plants are 3 to 4 inches high. On the other hand, late sown flax is easily injured by fall frost occurring before the crop is ripe. In the Great Plains area, April and May seedings usually produce the highest yields. Seedings as late as the first week in June, however, will ripen before frost.

Data on the time of seeding as influencing yield, as reported by a number of stations, are summarized in Table *599a*.

599a. *Date of seeding flax; yields in bushels per acre. Summary.*

Station Bulletin No.	Range in Seeding	No. of Years	Order of Seeding, Earliest to Latest								Names of Sub-stations
			1	2	3	4	5	6	7	8	
N. D. Bul. 178	4/20-6/10	7	15.6	16.1	15.4	13.8	8.4	3.5			Fargo
	4/21-6/15	1	2.3	6.0	7.7	5.6	3.9				Dickinson
	5/1 -6/1	10	8.3	8.4	7.9						Mandan
S. D. Bul. 213	3/15-6/15	10	0.5	8.3	10.6	9.2	9.5	3.0	1.3		Highmore
	4/15-6/15	12	9.6	9.1	8.1	5.1	3.6				Eureka
	4/15-6/15	11	4.1	3.5	2.3	3.4	3.9				Cottonwood
Kans. Bul. 144	3/28-6/6	2 & 3	11.6	11.3	11.4	9.7	11.2	7.5	6.1	4.1	

600. Rate of Seeding. Dillman states that the usual rate of seeding in western Minnesota, in eastern South Dakota, and eastern North Dakota is 28 pounds per acre; farther east where the rainfall is greater, 30 to 40 pounds; in the northern Great Plains area under dry farming conditions, 20 to 25 pounds, and under irrigation, 40 to 45 pounds per acre.

Hyslop[3] states that fiber flax is broadcast at the rate of 100 to 110 pounds per acre, while when planted for seed the highest yield at Corvallis, Oregon, was secured from 40 to 50 pounds per acre. Under dry-land conditions 15 to 20 pounds per acre is recommended.

Comparative yield data from different rates of seeding at a number of stations are summarized in Table *600a.*

600a. Rate of seeding flax; yield, bushels per acre. Summary.

REFERENCE	YEARS	POUNDS								
		10	15	20	25	30	35	40	45	60
N. Dak. Bul. 178										
Mandan	7	8.9	9.3	9.9	9.7					
Fargo	5		13.6		14.6	15.3		15.5	15.5	
Kans. Bul. 144	3		10.63			11.71			11.30	10.70
S. Dak. Bul. 213	8			5.8	6.4	6.6	6.4	7.4		

601. Method of Seeding. Wright[4] states that in planting flax the same machine is used as for seeding small grain. The drill is said to be preferable on most soils but there is danger of planting the seed too deep. On soils which crust readily and severely, a broadcaster will usually give better results than the drill.

602. Harvesting Seed Flax. Most investigators state that flax should be cut when fully ripe, the stems golden and most if not all of the leaves fallen. If cut too green, flax does not cure out readily and the yield of seed is apt to be reduced and of inferior quality, while if allowed to become overripe it deteriorates because of the exposure, and the shattering is increased. Flax is generally cut and bound with the grain binder though the header is also used. The crop is threshed with the grain separator, care being taken to feed the flax evenly into the machine.

603. Harvesting Fiber Flax. The best quality of fiber flax is obtained when the plant is harvested before the seed is fully mature.

Self-rake reapers, mowing machines, and grain binders have been used for cutting fiber flax. The usual method of harvesting in European countries is by hand pulling, for when fiber flax is cut with a

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[3] Hyslop, G. R.—"Flax in Oregon." *Ore. Agr. Expt. Sta. Circ. 60.* 1925.
[4] Wright, A. H.—"Flax in Wisconsin." *Wis. Agr. Coll. Ext. Cir. 203.* 1926.

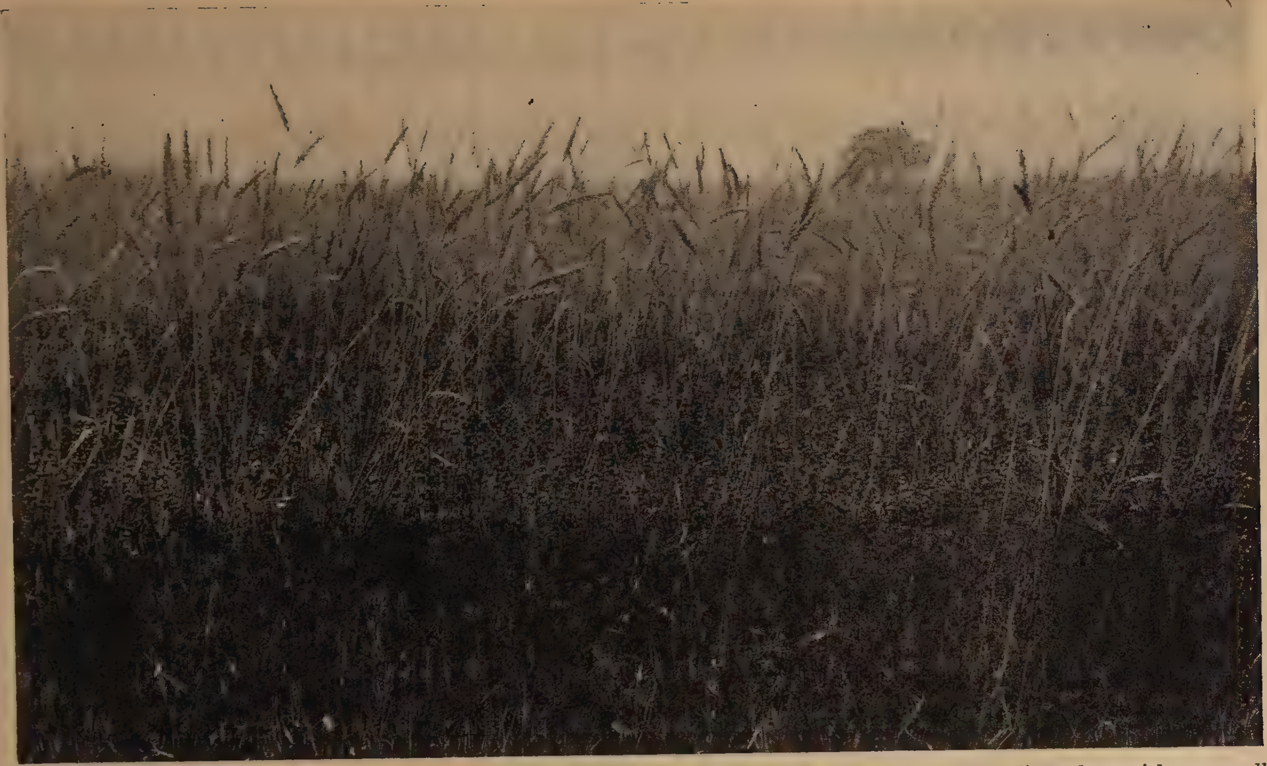

FIG. 113.—Spring wheat and flax grown together. *In certain areas the practice of seeding flax with a small grain crop has become general. Under what conditions is this profitable? Will this practice result in an increase in the production of flax in this country?*

machine a varying quantity of fiber is left in the stubble, and at the cut ends of the straw the fiber becomes badly discolored or otherwise injured. The first operation after the flax has been harvested is to remove the seed. An ordinary threshing machine cannot be used for this as it is essential that the straw be kept straight and that the seed be removed without breaking or doubling or otherwise injuring the straw. After the seed has been removed, retting begins,—a treatment to loosen the fiber from the woody portion of the stalk so that it may be readily removed. In dew retting the flax straw is spread out in straight rows in a field to allow the action of rain, dew, or snow to remove the gummy material from the straw, which causes the fiber to adhere to the woody portion of the stalk. This usually takes from 2 to 8 weeks, depending upon the climatic conditions. The best flax fiber is obtained from Belgium where flax is water retted. In this method the flax is immersed in water for from 6 to 15 days.

The average yield of fiber flax in this country is from 1½ to 2½ tons of unthreshed straw per acre, from which 4 to 7 bushels of seed and 300 to 450 pounds of cleaned, retted fiber may be obtained.

604. Flax-Grain Mixtures. Arny[5] states that a combination of wheat and flax has several advantages over flax alone, particularly in the control of such weeds as lamb's quarter and bindweed. The combination crop also gives a relatively higher yield than either crop alone. The combination is as easy to handle as a pure crop of wheat, and if one of the crops in the combination is injured or makes a total failure the other may produce at least a partial crop. Among the disadvantages of the mixture is that there is some cost in separating the seed flax and wheat before it can be marketed and the mixed straw cannot be used by the industries. Dry flax straw reasonably free from weeds, on farms within 150 miles of market, has a value of approximately $3.00 a ton in the stack, up to the quantity needed by the industries. Arny suggests that when wheat and flax are to be used in mixture 30 to 45 pounds of wheat be sown with 42 pounds of flax.

Stoa states that tests made with flax-wheat mixtures did not warrant a general recommendation for this crop under North Dakota conditions and McKee makes the same report for Montana. Hume states that the mixed crop cannot be recommended for the drier portions of western South Dakota but that in the eastern part of the state somewhat higher relative yields may be expected from growing flax and wheat in mixtures than growing each crop separately. He states that the usual practice is to mix the wheat and flax equally at the granary and then seed at the rate of 55 to 60 pounds of the mixed grain per acre.

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[5] Dillman, A. C., Arny, A. C., McKee, Clyde, Stoa, T. E., and Hume, A. N.—"Seed Flax as a Farm Crop in 1925." *U. S. Dept. Agr. Dept. Cir. 341.* 1925.

Wright[6] compared oats, barley, and wheat in admixture with flax and reports that wheat and flax make the most satisfactory mixture and may be used to advantage in sections where spring wheat is commonly grown.

BUCKWHEAT

Combined Asiatic and European Russia produce more buckwheat than any other country, with an average production of about 55,000,000 bushels. France produces approximately 20,000,000 and the United States 17,000,000 bushels. New York and Pennsylvania produced 64.5 per cent of the entire crop in the United States in 1919.

605. Classification and Origin. Buckwheat belongs to the *Polygonaceae* family, to the genus *Fagopyrum* and to the species *esculentum.* Buckwheat probably originated in Asia and came into Europe in the Middle Ages, reaching Germany early in the fifteenth century.

606. Varieties and Types. The varieties of buckwheat commonly grown are the Japanese, the Silverhull, and the Common Gray. The seeds of the Japanese are the largest and are dark brown in color. The Silverhull seed is smallest and glossy or silvery in appearance. The Tartary buckwheat, also known as India wheat or "rye buckwheat" is not generally grown. It has a dull, roughened seed with slightly notched angles and furrowed surfaces.

607. Adaptation of Buckwheat. Leighty states[7] that buckwheat requires cool, moist weather, especially at blooming time. On land on which wheat or even rye cannot be grown with profit, buckwheat will often produce a profitable yield. It does well on acid soils. Soils high in nitrogen are not suited to buckwheat as they stimulate a top growth and the crop usually lodges badly. Buckwheat is grown far north, due to the fact that it requires only a short growing season but it is quickly killed by frost or freezing temperatures. When the plants come into bloom in hot weather or in dry weather the flowers often blast and produce no grain (Figure 30).

608. Description of the Plant. Buckwheat produces only one main stem per plant; there are no tillers or branches. The triangular, heart-shaped leaves are ranged alternately on the stem. The flowers vary from white to a light red or pink. They are borne in racemes at the end of the stem or on short pedestals. Other plants related to the buckwheat are common dock, smartweed, bindweed, and sorrel.

609. Uses of Buckwheat. Buckwheat is grown almost entirely for the seed or grain which is made into flour and used almost entirely in griddle cakes. Middlings made in the manufacture of buckwheat flour are high in food value for livestock. The whole buckwheat grain is a good poultry feed. The entire crop is often plowed under for green manure purposes. Buckwheat is often used as a smother crop to destroy weeds as the seed germinate quickly and the plants soon cover the ground, shading it so that weed growths are crowded out. As a green manure crop the plant decays quickly when plowed under and buckwheat seems to be able to utilize relatively insoluble mineral soil constituents and will flourish on soil too poor for the cereals. Buckwheat is also used as an orchard cover crop and is one of the leading honey plants. It produces a great many flowers, continuing to bloom through a long period of time. Leighty states that it has been estimated that an acre of buckwheat, growing under good conditions, may supply as much as 150 pounds of honey in a season. In sections where buckwheat is not much grown it is a valuable emergency crop which may be seeded late in the season on land where other crops have failed.

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[6] Wright, A. H.—"Flax in Wisconsin." *Wis. Agr. Col. Ext. Cir. 203.* 1926.

[7] Leighty, Clyde E.—"Buckwheat." *U. S. Dept. Agr. Farmers' Bul. 1062.* 1919.

610. Seedbed for Buckwheat. Buckwheat is often sown on very poorly prepared land although it does best on well prepared soil. The preparation of the seedbed, in general, would be very similar to that for corn.

611. Date of Seeding Buckwheat. The seeding time for any locality is determined fairly accurately by allowing a period of 12 weeks for growth before the first killing frost is expected. The seeding is made as late as possible so that blooming will not occur in the hot, dry portion of the season.

612. Rate of Seeding. Leighty states that buckwheat should generally be seeded at the rate of 3 to 4 pecks but that if the soil is fertile and free from weeds and the seed of good vitality, as little as 2 pecks may be sufficient if sown with a drill. It is often the practice to make heavy sowings on rich soil as the denser growth somewhat prevents lodging.

In *W. Va. Bulletin 200*, Odland reports 4 years' results in seeding buckwheat at the rate of 2, 3, 4, 5, and 6 pecks per acre and 2 years' results with 8 pecks. The average yields were: 22.3, 22.3, 22.2, 22.2, 21.5, and 21.9 bushels per acre, respectively.

Stemple[8] reports 4-year average yields for seedings made at the rate of 2, 3, 4, 5, and 6 pecks per acre as 20.2, 23.46, 24.13, 24.27, and 24.52 bushels per acre, respectively.

613. Harvesting Buckwheat. Leighty states that buckwheat is usually harvested when the seeds from the first lot of blossoms are

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[8] Stemple, F. W.—"Experiments with Buckwheat." *W. Va. Agr. Expt. Sta. Bul. 171.* 1919.

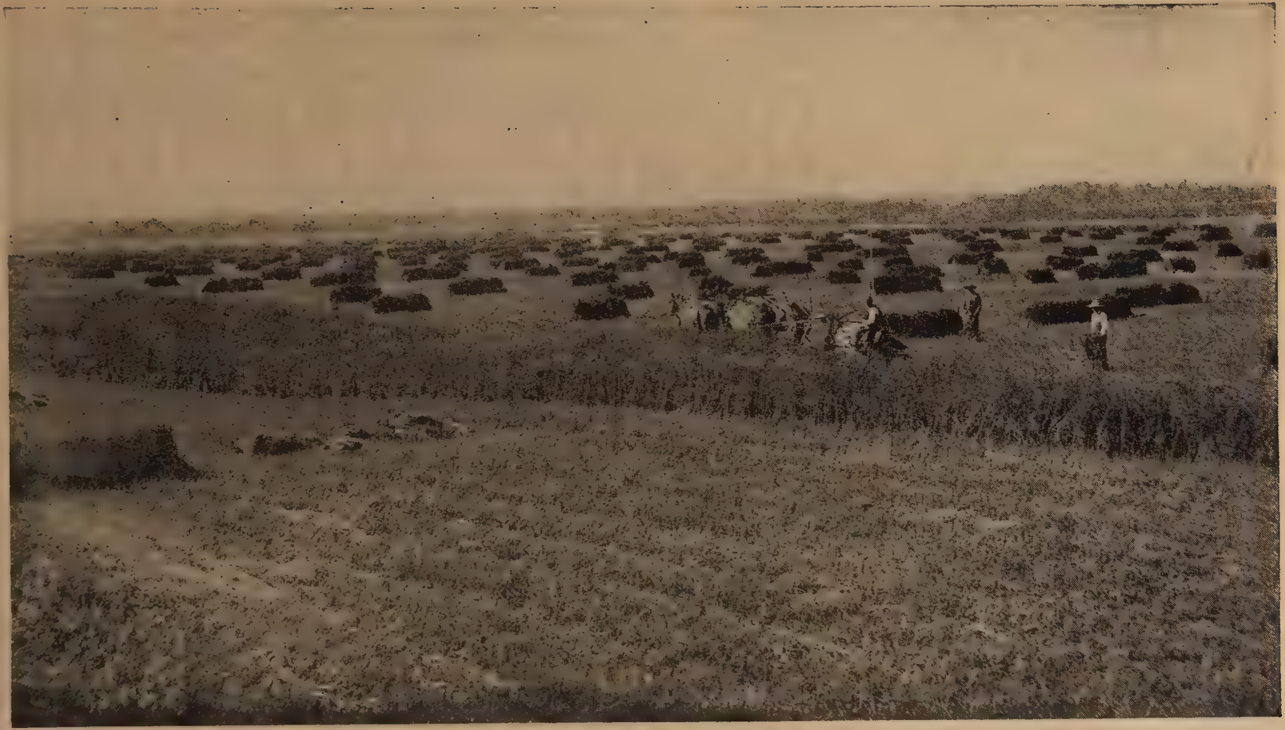

FIG. 114.—Buckwheat is usually cut with a binder and threshed direct from the shocks which are made long and narrow to facilitate rapid drying. *How do you account for the large acreage of buckwheat in New York and Pennsylvania and the small acreage in the central corn belt?*

fully mature. If frost threatens, cutting may begin as soon as the seeds from the first lot of blossoms are fully formed. The crop should be cut in the morning when the dew is on or in damp weather to prevent shattering of the grain. An ordinary grain binder may be used for cutting, in which case the bundles are set up in long, narrow shocks. A considerable part of the buckwheat crop in the United States is cut with the cradle. This is often necessary on account of the rough land used for the crop.

Buckwheat is often threshed with a flail. When a flail is used, the grain should be thoroughly dry and the weather good. Ordinary threshing machines will crack a good bit of grain unless the concaves are removed. The grain is very easily threshed.

RICE

Rice is one of the most important food crops of the world. It forms a large portion of the diet of people living in tropical and in warm temperate climates. The greater part of the world crop is produced in eastern and southeastern Asia. The United States produces about one per cent of the total world crop (Figure 61).

614. Classification and Varieties. Rice belongs to the grass family and is a true cereal. It is located in the tribe *Oryzeae* and to the genus *Oryza*. *Oryza sativa* includes the cultivated rices. The number of different varieties of rice is very large; it has been estimated that there are 5,000 distinct varieties in the world. The rices widely grown in the United States are the large white and yellow kerneled varieties. Small seeded varieties are grown in some of the Oriental Asiatic countries, particularly in Japan. Chambliss[9] states that the leading rice varieties of California are the short-grained rices, the Wataribune, and 2 unnamed varieties known as C. I. 1564 (Butte) and C. I. 1600 (Colusa). Honduras and Blue Rose Rice are grown in Louisiana, Texas, and Arkansas. Honduras is grown in all prairie sections, producing its largest yields on land that has not been cropped too heavily to rice.

615. The Plant. The rice plant is an annual with a shallow fibrous root system; it tillers abundantly under favorable conditions. The head is a panicle, with one-flowered spikelets borne on short pedicels. The outer glumes are very short scales, while the kernel is enclosed in the flowering glumes, or lemma and palea, which remain attached after threshing.

616. Adaptation of Rice. Rice cultivation is limited in general by temperature and by its water requirement. Ordinary rice will not succeed at temperatures lower than the warmest part of the temperate zone. In the wild form rice is a marsh plant which grows along the banks of streams and in cultivation it usually requires irrigation. The upland or prairie rice is only slightly different from ordinary rice. It appears to require less water and usually is not irrigated, though it yields more when water is supplied than when grown without irrigation. Upland rice in the United States is grown on comparatively small areas and for home use (Figure 26).

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[9] Chambliss, Charles E.—"Rice Growing in California." *U. S. Dept. Agr. Farmers' Bul. 1141.* 1920.

617. The Seedbed and Seeding. In preparing the seedbed for rice, the land is usually fall or winter plowed and the surface of the soil worked into a finely pulverized condition.

The crop is usually sown with a grain drill, although it may be seeded broadcast. Drilling seems to be the preferred method. Chambliss[10] states that in Louisiana the Honduras variety gives the highest yield when seeded at the rate of 80 pounds per acre, though the medium grained varieties are seeded at the rate of 65 to 75 pounds per acre.

The seeding rate is less on a well prepared seedbed than on a poor one. When seeding on weedy land, the rate of seeding is increased.

Chambliss reports that on the prairies the greater part of the rice crop is sown from April 1 to May 15. May 1 is approximately the best date for sowing rice in northern Arkansas.

Water is usually applied to a depth of 1 to 2 inches when the plants have reached a height of from 6 to 8 inches, and the depth increased slowly until the maximum depth of 5 inches is obtained about the time the plants have reached 2 feet in height. This depth of water is maintained throughout the balance of the growing season.

618. Harvesting the Crop. Rice is ordinarily harvested with the grain binder. Rice should not be left standing until fully ripe, but should be cut promptly when the kernels of the lower part of the heads are not entirely hardened. At the proper stage for cutting the heads are drooping. If cut too early, the crop will have a large per cent of imperfectly formed kernels. If cut later, there will be a loss of grain from shattering. Rice is cured in the shock and threshed when the kernel is hard and the straw is thoroughly dry.

STUDY QUESTIONS ON CHAPTER XXI

1. Describe and give a brief history of flax.
2. Distinguish the types of flax and give the adaptations of each type.
3. Give instructions for growing and harvesting a crop of seed flax.
4. Give instructions for growing and harvesting a crop of fiber flax.

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[10] Chambliss, Charles E.—"Prairie Rice Culture in the United States." *U. S. Dept. Agr. Farmers' Bul. 1092.* 1920.

5. Would you recommend the flax-wheat mixtures? If so, under what conditions?
6. Describe, give a brief history, and state the uses of buckwheat.
7. Under what conditions would you advise the growing of buckwheat?
8. Give instructions for growing and harvesting buckwheat.
9. Describe and give a brief history of rice.
10. Why is rice so extensively grown in parts of the Orient?
11. Describe and give the regions of production of important types of rice.
12. How is it possible for the rice plant to grow on flooded land while other cereals cannot do so?
13. Give instructions for the growing and harvesting of rice.
14. Is rice growing increasing in this country? Explain.

APPLICATION ASSIGNMENTS ON CHAPTER XXI

1. Your landlord has suggested that you seed 20 acres of flax. He states that the price is $2.20 per bushel and the Argentina crop is short. He asks for your opinion as to the advisability of growing and the methods of production. Will you grow flax? Answer this request.
2. Last year your corn was destroyed by hail. As it was too late to replant, you seeded 20 acres of buckwheat. It brought a higher return than your oats. You are considering substituting buckwheat for oats regularly. Will you do so? Outline the considerations that influence your judgment.
3. Wheat is spoken of as the "staff of life" for the white race while the yellow race tends to the use of rice. How do you account for this? What are the conditions which have limited rice culture in the U. S.?

CHAPTER XXII

COTTON

Cotton is the great crop of the South. It is also the greatest commercial crop of the United States. In value the cotton crop ranks second only to corn (Figure 25).

619. History and Production of Cotton. The making of cloth from cotton fiber evidently antedates history. Early literature indicates that by 1500 B.C. cotton production and spinning was the common practice in India, the leading cotton country of the world for a long period of time.

Columbus found cotton growing in the West Indies and it was found by other explorers in Mexico and Peru. Cotton production did not become important in the United States until Whitney invented the saw gin in 1793. Exports of cotton until about 1788 had never been more than 17 bales. In 1788, over 100 bales were exported; in 1800, 91,700 bales; in 1840, 1,300,000; in 1860, 3,000,000; in 1900, 6,500,000, and in 1920, 6,300,000. The largest crop of cotton produced in the United States was the crop of 1926, which was 18,000,000 bales. The estimated world total, including China, for 1925-1926 was 27,700,000 and in this year the United States produced 16,100,000 bales. India produced 5,000,000; Egypt, 1,600,000; China (estimated), 2,100,000; Brazil, 600,000; Asiatic Russia, 700,000.

Average yields of lint cotton per acre for the various countries are reported as follows: United States, 167 pounds; India, 86 pounds; Egypt, 390 pounds; Brazil, 218 pounds, and Asiatic Russia, 218 pounds (Figure 8).

620. Adaptation in the United States. Angelasto *et al.*[1] state that the average summer temperature along the northern boundary of the cotton belt is 77° F. This temperature appears to be the limit beyond which commercial production becomes unprofitable. The length of the growing season along the northern border is about 200 days. The rainfall in the cotton belt ranges from 23 inches in western Oklahoma and Texas to 55 inches in eastern North Carolina and 60 inches in southern Mississippi. The general rainfall throughout the South is from 30 to 50 inches. In the cotton belt, 6 to 16 inches of rainfall in the spring with a somewhat larger amount in the summer and a small amount in the fall are desirable. Wooten[2] states that cotton may be expected to produce crops worth harvesting, at least part of the time, in the Great Plains area of Texas, where the normal rainfall is 17 inches or more, of which approximately 75 per cent falls during the growing season. Wooten also estimates that there are approximately 3,000,000 acres in this section which may be used for cotton. The distribution of cotton production in the United States has been considered in Chapter II.

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[1] Angelasto, A. M., *et al.*—"The Cotton Situation." *U. S. Dept. Agr. Yearbook 1921*, p. 341.

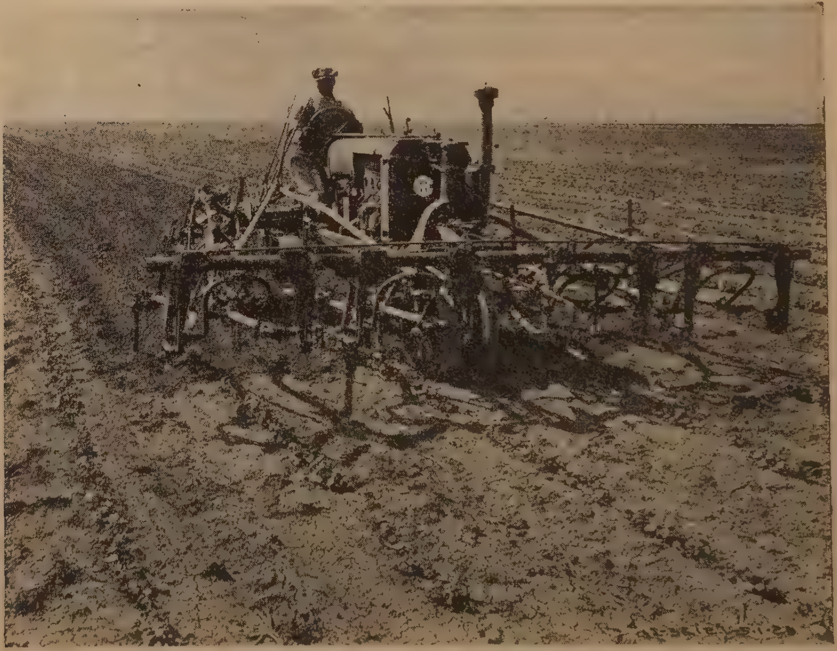

FIG. 115.—Cotton culture has become an important industry in recent years in parts of Oklahoma and Texas where the topography is suitable to the use of the most efficient equipment for planting, cultivation and harvesting. *What influence is this development likely to have on the cropping practices of the old cotton belt?*

621. Classification of Cotton. There are 7 recognized species of cotton belonging to the genus *Gossypium* and the family *malvaceae* or mallow family.

(1) *Gossypium barbadense.* This group includes the Sea Island cotton. It is grown in the West Indies, eastern South Carolina, Georgia, northeastern Florida, and on adjacent islands. The stems

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[2] Wooten, E. O.—"Cotton in the Texas Plains Area." *U. S. Dept. Agr. Yearbook 1926*, pp. 273-274.

of Sea Island cotton are erect, round, and smooth. The leaves are divided into 3 to 5 nearly equal lobes. The petals are pale yellow with purple markings. The bolls are 3 locked with 6 to 9 seeds in each lock. The seeds are ovate and nearly naked and the lint creamy white, long and silky. The fibers range from 1½ to 2½ inches in length.

(2) *Gossypium hirsutum.* Practically all of the American upland and certain Mexican, Indian, and Egyptian varieties belong to this species.

FIG. 116.—The Experiment Stations in the cotton belt compare a great many different varieties and strains of cotton. It is not uncommon to find one variety producing 50 per cent more seed cotton than another. (Oklahoma Station.) *Can you map the cotton belt showing the leading varieties of cotton in the different sections?*

The plants grow to a height of from 2 to 4 feet. The older parts of the plant are smooth but in the younger portions the branches are covered with whitish hair. The leaves vary in shape, but are 3 to 5 shallow lobed. The petals are pale to deep yellow, some forms having purple spots. The bolls are 4 to 5 lobed, somewhat rounded, the seeds ovate and covered with a dense covering of grayish, rusty, or green fuzz. The lint is fine to medium coarse ranging from ½ to 1$\frac{3}{16}$ inches in length.

The two species described above include most of the cotton in the United States.

The other species are (3) *Gossypium braziliense,* (4) *Gossypium purpurascens,* (5) *Gossypium peruvianum,* (6) *Gossypium her-*

baceum, (7) *Gossypium nanking*, and (8) *Gossypium arboreum* or tree cotton.

622. Varieties of Cotton. Each community grows a number of different so-called varieties of cotton, though in many cases these same types or varieties may be found growing in other sections under different names. Brown[3] states that in Mississippi there are not more than 20 distinct varieties, and in the whole cotton belt probably not more than 30.

Tyler[4] listed almost 400 varieties of cotton in the United States in 1910 but only a very small number of these are in existence today. Some of the more important varieties now being grown, with a few characteristics, are listed in Table *622a*.

623. The Cotton Plant. The cotton plant makes a growth of from 2 to more than 5 feet in height with many side branches, usually extending down to within a few inches of the surface of the soil. The leaves are alternate, arranged in a spiral around the stem. In the axis of each leaf there are rudiments of buds which may develop into branches. One of these buds may produce a fruiting branch and another a vegetative branch. Vegetative branches do not produce flowers and fruit except on lateral branches from the main branch. The leaves in general are palmate, petiolate, and 3, 5, or 7 lobed. They vary from 3 to 7 inches in length and from 2 to 5 inches in width. Both leaves and stems are generally covered with fine hairs, although some sorts are glabrous or smooth.

The cotton plant has a tap root system which goes directly down into the ground from 1 to 4 feet, depending upon the variety of cotton and the soil environment. The spread and depth of the root system has been discussed. **(125)**

The flowers are pedicelled and arise from the fruiting branch. At first the bud is enclosed in 3 small leaf-like bracts. At this stage they are known as "squares." These bracts surround and serve to protect the tender, growing floral part. Cotton flowers are rather large and showy, resembling the flower of the hollyhock. Flowers open just before or at sunrise and close at night after being fertilized. The flowers vary in color from white, through cream or yellow to a reddish purple, depending upon the age of the flower and the variety of the cotton. The petals of upland varieties generally turn dark with age. White flowers, on the second or third day after opening, may be pink or reddish purple in color. Each flower has 5 petals and numerous stamens arranged in 5 rows on the staminal column. The pistil is

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[3] Brown, Harry Bates—*Cotton*, p. 41, McGraw-Hill Book Co. New York. 1927.

[4] Tyler, Frederick J.—"Varieties of American Upland Cotton." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 163.* 1910.

622a. *Important varieties of cotton.*

VARIETY	TYPE	LENGTH OF STAPLE	BOLLS PER POUND	MATURITY
Allen Long Staple	Small boll semi-cluster	1–7/16	78	Medium
Acala	Medium boll intermediate	1–¼	52	Medium
Cleveland	Round boll not uniform	1–5/16	60	Medium early
Wanamaker Cleveland	Round boll spreading	15/16	65	Early
College No. 1	Round boll non-cluster	15/16	60	Medium early
Cooks Improved	Round boll not uniform	⅞	63	Medium early
Delfos	Small boll low-spreading	1–¼	75	Very early
Dixie	Small boll wilt resistant	⅞	75	Medium late
Express	Small boll spreading	1–3/16	76	Early
Half and Half	Small boll compact	¾	75	Medium early
King	Small boll short branched	15/16	90	Very early
Lone Star	Big boll med. spreading	1–1/16	48	Medium
Mexican Big Boll	Big boll intermediate	1	58	Early
Pima	Tall bushy plants	1–⅝		Early
Rowden	Big boll stocky growth	15/16	55	Medium early
Salsbury	Small boll spreading	1–⅛	78	Early
Texas Burr	Big boll stocky plants	15/16	67	Medium
Toole	Small boll wilt resistant	15/16	73	Medium late
Trice	Small boll compact	1	75	Very early
Triumph	Big boll large stocky plants	1–⅙	56	Medium
Truitt	Big boll semi-clustered	15/16	56	Medium
Webber	Big boll large plants	1–¼	60	Medium
Yuma	Tall bushy plants	1–½		Medium

divided into 3, 4 or 5 stigmas and the ovary has 3 to 5 cells, corresponding to the locks of the boll. When the boll has reached its full growth, before opening, it ranges in size from an ordinary hen's egg down to about one-third this size. At maturity the boll splits or cracks and the swelling of the cotton inside expands and pushes back the sections of the boll so that they extend at right angles to the axis. The fibers of each lock of cotton hold together and the lock is held in the boll by being wedged between the adjacent parts of the burr at the lower end.

The first blossoms appear from 7 to 11 weeks after planting, and the flower buds or squares may be distinguished from 3 to 4 weeks before the flowers open. After the flowers open, a period of 45 to 70 days elapse before the bolls open, the length of time being determined by the variety, temperature, humidity, and age of the plant.

624. Fiber. The cotton fiber is an outgrowth produced by the extension of the cell wall of a single epidermal cell. There are 2 types of fibers produced. Certain cells produce outgrowths which continue growth and make the real cotton fiber. Others produce a second type which stop growing without attaining much length. These short, epidermal fibers or hairs are known as "fuzz" and remain attached to the seed after the lint or long fibers have been removed. Fiber cells are cylindrical until about the time the boll begins to open and contain living protoplasm until this time.

At the opening of the boll, moisture evaporates from the fibers and they become thoroughly dry. With this loss of water the cylindrical cells collapse assuming a flattened form. Accompanying the flattening, the fiber twists. It is this flattening and twisting which causes the lock of seed cotton to expand. Balls,[5] studying the growth of lint hairs in Egyptian cotton, found that the lint cells attain full length during the first half of the growth period of the boll, or in about 25 days. During the second half, the walls of the fiber were thickened by the addition of cellulose.

Evans[6] estimates that 85 per cent of the fiber is cellulose and that 2 per cent of its weight is due to a waxy deposit which makes cotton somewhat impervious to water. Each cotton fiber is a tubular, hair-like cell, varying from 0.0001 to 0.0025 of an inch in diameter and from ¾ to 2½ inches in length.

The character of the fiber depends to a considerable extent upon the growing conditions.

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[5] Balls, W. Lawrence—"The Existence of Daily Growth Rings in the Cell Wall of Cotton Hairs." *Roy. Soc.* [*London*] *Proc. Ser. B.* Vol. 90, pp. 542-555. July, 1919.

[6] Evans, W. H.—"Botany of Cotton, The Cotton Plant." *U. S. Dept. Agr. Bul. 33.* 1896.

The relative value and some of the characteristics of types of lint grown in various cotton regions of the world have been indicated by Cook[7] as shown in Table *624a*.

624a. Selected list of cottons, showing character and relative value.

COUNTRY	VARIETY	AVERAGE LENGTH (INCHES)	RELATIVE VALUE	COLOR	REMARKS
America ...	Sea Island (South Carolina)	2	230	Cream	Silky, regular
	Sea Island (Georgia & Florida)	1⅝	215	Cream	Silky, regular
Egypt	Sakellaridis	1½	173	Dark cream	Silky, short
	Nubari	1⅜	160	Light brown	Silky, weak
America ...	Long-staple Upland	1¼	160	White	Soft, strong
	Short-staple Upland	1	100	White	Soft, strong
India	Tinnivelly	⅞	95	White	Best of Indians
	Surat, Broach, etc.	⅞	91	Light brown	Harsh, strong
	Sind	⅝	71	Dull white	Poor
China		¾	88	Dull white	Rather harsh

625. The Seed. Within each boll of cotton the seed, which are attached to the center, are released at maturity. The number per lock varies from 6 to 10. The seed are oblong in shape, pointed towards one end and range from ¼ to almost ½ inch in length. The legal weight per bushel varies from 30 to 33⅓ pounds for the common upland or fuzzy seeded varieties. In Sea Island cotton the seed are black and free from fuzz except at the tip end, and weigh 44 pounds per bushel. Cotton seed is usually sold by the 100 pounds rather than by the bushel.

The seed coat is dark brown or black in color. The embryo makes up almost the entire kernel and consists of 2 cotyledons or seed leaves, which are much folded and well supplied with rich food. Throughout the cotyledons are numerous dark spots which appear on the seed leaves of the young plants. These are oil glands or resin cavities.

With the germination of the seed the hypocotyl or primary stem enlarges and lengthens rapidly. It becomes hard and the top of the arch pushes its way upwards and out of the ground and then straightens up, freeing itself from the old cotton seed and unfolding the seed leaves.

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[7] Cook, O. F.—"Principal Commercial Types" [of cotton]. *U. S. Dept. Agr. Off. Farm Mgt. Atlas of Amer. Agr.* Part 5, Sec. A, p. 5. 1918.

626. Composition of the Cotton Plant. Fraps[8] states that where yields of 1000 to 1200 pounds of seed cotton per acre are produced the amount of stalk for each 300 pounds of seed cotton is about 350 pounds; leaves, 150 pounds; bolls, 50 pounds, and burrs 160 pounds. The probable needs of the cotton plant for 300 pounds of seed cotton or 100 pounds of lint are estimated to be 7 pounds of phosphoric acid, 25 pounds of nitrogen, and 15 pounds of potash. The leaves were found to be moderately high in protein and in ether extract and should have considerable feeding value.

627. Breeding Cotton. Cotton often runs out, the plants decreasing in size, vigor and yield year by year. This will not occur if a pure strain is obtained at the start and care is taken that seed is not mixed at the gin, nor this strain of cotton grown near other cotton. Preferably a whole community should grow the same strain of cotton and a local gin handle only the one variety.

The chief means used in the past in improving cotton has been through selection. Some of the characters considered have been the quantity of seed cotton produced per acre, the production of lint, actual percentage of lint, number and size of bolls, earliness, length of staple, location of the branches and length of the internodes. In making selections the seed of plants most closely approaching the ideal of the breeder are saved separately and planted in different rows, and the best plants from the best rows carried over for further testing and increase. Most of the leading cotton varieties have come about as a result of such selection.

628. Yield Tests with Cotton. In various parts of the cotton belt interest has been stimulated in community cotton improvement. The strain or variety which has been proven to give the highest yield in a particular section is adopted by the community, and one particular gin set aside for ginning this particular strain of cotton. In the yield tests a number of different varieties which are thought to be good in the community are planted side by side under uniform conditions, harvested separately, the yields determined, and ginning tests made to determine the highest yielding variety possessing the desirable lint qualities.

In many sections, the local cotton market does not recognize differences in length and quality of fiber, in which case the grower raising long staple cotton does not get what the cotton is worth, while the person growing extremely short staple cotton with a high linting per cent gets more than his product is worth. This situation has not been conducive to an improvement in the quality of cotton. Community cotton growing should remedy this condition.

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[8] Fraps, G. S.—"The Chemical Composition of the Cotton Plant." *Tex. Agr. Expt. Sta. Bul. 247.* 1919.

629. Pollination in Cotton. Webber[9] stated in 1902 that there was from 5 to 10 per cent of crossing between varieties of upland cotton when grown in adjacent rows.

Ricks and Brown[10] report crossing ranging between 4.9 to 11.1 per cent between red-leaved and green-leaved varieties of cotton. When planted in alternate hills, the crossing was 18.5 per cent.

Arkansas[11] reports that cotton rows on either side of a row of red cotton received about one per cent mixture; cotton 2 rows from the red, 0.5 per cent mixture, and the crossing in more distant rows practically negligible.

The amount of crossing which takes place between two varieties only a few yards apart seems to be limited, from all experimental work, although there may be some crossing in certain fields separated a quarter of a mile or more. The practical way to maintain pure seed and prevent crossing and degeneration is to grow only one variety in a community.

630. Shedding in Cotton. Buie[12] states that as many as 50 per cent of the bolls of most varieties of cotton are shed before reaching maturity. The shedding may take place before the corolla of the flower falls, generally within 8 to 10 days after flowering. The conditions which influence shedding are drouth, water-logged soils, deep cultivation late in the season, and weevil damage. The mechanics of shedding is much the same as takes place in other plants which drop their fruit or leaves.

Lloyd[13] found that the majority of flowers fall the second day after an injury but that a high rate continues for 5 days afterwards. Various workers found that a lack of rain and the prevention of fertilization due to rain was a big factor in inducing shedding.

631. Culture of Cotton. In general, the cultural practices used in growing cotton in all parts of the world are poorer than those employed for other important crops. The general principles relative to seedbed preparation as previously discussed apply to the seedbed for cotton, though naturally there are some variations due to the nature of the plant and the section of the country in which it is grown. For example, cotton is usually planted on beds. These beds are made with a turning plow in which 2 furrows usually are thrown together. The middle buster is then used to make a little furrow at the top of the ridge or bed, in which fertilizer is distributed and mixed with the soil. Dirt is thrown back over this furrow and the cotton planted on top of the bed. In the South a good bit of this plowing is done with a one-horse turning plow. In India, practically all the plowing is done with wooden plows tipped with metal, 4 or 5 trips across the field being required for each row. The usual plowing is very shallow. There is a saying in the cotton belt that cotton will not grow well until the roots strike hard ground. Bedding is distinctly a process of the eastern and southern half of the cotton belt. Level planting is common in the western half, or, if beds are used, they are usually smoothed down until they are almost level with the middles Time and depth of preparation of the seedbed and methods of moisture control are the same as in other crops.

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[9] Webber, Herbert J.—"Improvement of Cotton by Seed Selection." *U. S. Dept. Agr. Yearbook 1902*, p. 370.

[10] Ricks, J. R., and Brown, H. B.—"Cotton Experiments. 1916." *Miss. Agr. Expt. Sta. Bul. 178.* 1916.

[11] Gray, Dan T.—"Thirty-seventh Annual Report (for) Fiscal Year Ending June 30, 1925." *Ark. Agr. Expt. Sta. Bul. 203.* 1926.

[12] Buie, T. S.—"The Fruiting Habits of the Cotton Plant." *Jour. Amer. Soc. Agr.* Vol. 20, No. 3, p. 194. Mar., 1928.

[13] Lloyd, F. E.—"Environment Changes and Their Effect upon Boll Shedding in Cotton." *N. Y. Acad. Sci. Annals.* Vol. 39, pp. 1-131. 1921.

632. Date of Planting. The planting of cotton is delayed until frost is over and the soil has become warm. Cotton seed are very likely to rot if planted in cold, damp soil. In 1917 Cates[14] reported

632a. Date of planting and method of planting cotton in different areas. Summary.

Range of Planting Date	Percentage of Farmers Planting			Average Distance Apart		Region Surveyed
	Level	On Beds	Listing	Rows (Feet)	Hills (Inches)	
Apr. 10 to May 10	..	100	..	3.5	16	Pemiscot Co., Mo.
Mar. 25 to Apr. 10	16	84	..	4	17	Mississippi Delta
Apr. 8 to Apr. 20	8	92	..	4	13	Robeson Co., N. C.
Apr. 15 to May 5	..	100	..	3.5	12.5	Mecklenburg Co., N. C.
Mar. 15 to Apr. 30	..	100	..	4	15.5	Barnwell Co., S. C.
Apr. 1 to May 1	16	84	..	3.5	13	Pike Co., Ga.
Mar. 15 to Apr. 20	28	64	8	4	16.5	Tift Co., Ga.
Mar. 10 to Apr. 30	20	80	..	3	13	Giles Co., Tenn.
Mar. 15 to Apr. 15	4	84	12	4	16.5	Bulloch Co., Ga.
Apr. 1 to May 20	4	96	..	3.5	14	St. Francis Co., Ark.
Apr. 1 to May 15	8	92	..	3	13	Ellis Co., Tex.
Mar. 25 to May 1	..	100	..	3.5	13.5	Chambers Co., Ala.
Apr. 1 to June 8	16	64	20	3.5	15.5	Johnson Co., Okla.
Mar. 1 to Apr. 15	8	92	..	4	13	Jefferson Co., Fla.
Apr. 1 to May 15	..	100	..	4	14	Lincoln Parish, La.
Mar. 1 to May 1	..	100	..	3.5	13	Lavaca Co., Tex.
Mar. 30 to May 30	4	96	..	3.5	12.5	Houston Co., Tex.
Apr. 1 to May 1	4	96	..	3.5	15	Monroe Co., Miss.
Mar. 1 to Apr. 15	40	20	40	3.5	18.5	Bexar Co., Tex.

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[14] Cates, H. R.—"Farm Practice in the Cultivation of Cotton." *U. S. Dept. Agr. Dept. Bul. 511*, p. 11. 1917.

the results of a survey of the usual planting dates in various cotton-growing communities as shown in Table *632a*. This also gives the method of planting, the spacing used, and the amount of seed planted per acre in each area. The student will do well to locate these areas on a map and give consideration to the soil, rainfall, and temperature of the different regions; also to consider changes which have occurred in cultural methods since 1917.

633. Width of Row. Cotton is planted in rows varying from 2½ to 5 feet apart. The richer the soil the wider the rows are spaced because the plants are larger on rich soil and require more space.

Brown[15] has summarized the literature bearing on the width of rows and the spacing in the row. While results varied greatly, due probably to differences in rainfall, length of fruiting season, etc., findings in Texas, Mississippi, and Georgia, in his opinion, all warranted certain conclusions. He states that in 24 tests under boll-weevil-free conditions 12-inch spacing in 3½ to 4 foot rows gave the best yields; that on the less fertile land, in the majority of cases, comparatively close spacing gave better results, while in a number of cases on rich land wide spacing gave best results. He concludes that closer spacing is desirable in boll weevil infested territory because fruit must be set within a very short time—a month or less—if there is heavy boll-weevil infestation. However 10 to 12 inches between plants is required to permit hoeing, as hoes are usually 7 to 8 inches wide.

634. Spacing in the Row. Brown states further that cotton plants should be spaced closely on poor soil regardless of the presence or absence of the weevil—2 to 4 plants per hill, with hills spaced 10 to 12 inches, in rows 3 feet apart, being desirable; but that on rich soil, in the absence of weevils, it is easy to get cotton spaced too closely. The presence of weevils makes comparatively close spacing desirable, but even so, on rich soil, not more than 2 stalks per hill are advisable, with 12 inches between hills, and rows 3½ feet apart. From his survey he finds closer spacing to be conducive to early maturity, or at least to boll opening.

Hall and Armstrong[16] report experiments in which cotton was planted at 3, 6, 9, 12, 16, 20, and 24 inches apart, the yields being highest with the 6, 9, and 12 inch spacing. These spacings also gave the highest per cent of the total yield at the first picking.

Tisdale[17] studied the effect of spacing on the yield and size of cotton bolls. He secured the largest yields from spacing 24 and 18 inches in the drill with 2 plants per hill.

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[15] Brown, H. B.—"Cotton Spacing." *Miss. Agr. Expt. Sta. Bul. 212.* 1923.

[16] Hall, E. E., and Armstrong, Geo. M.—"Cotton Experiments at Florence," *S. C. Agr. Expt. Sta. Bul. 225.* 1926.

[17] Tisdale, H. C.—"The Effect of Spacing on the Yield and Size of Cotton Bolls." *Jour. Amer. Soc. Agron.* Vol. 20, No. 3. pp. 298-301. 1928.

Mooers,[18] from a study of the spacing experiments in different states, found that in most sections of the country the best spacings were most frequently between the 12 and 16 inch limits. He takes this as a strong indication that there is a definite and common best spacing which is of universal application. However, because of the wide variations in different seasons he suggests that exceptions may be found where either closer or wider spacings than the average would be warranted. He also summarized data in Texas from the standpoint of the spacing to be used on poor and rich soils and found that, contrary to popular opinion, the best spacing was closer under conditions of high than under conditions of low productivity. The difference, however, was very small.

A survey of the recommended spacing of cotton plants was made among agronomists in the cotton belt. The results of this survey, supplemented by their published recommendations, is given in Table *634a*.

634a. Spacing of plants recommended by agronomists.

STATE	ROWS	PLANTS IN ROW	SEEDBED PREPARATION
Ill.	3 ft. 6 in.	8 to 10 in.	As for corn
Mo.	3 ft. 4 in.	10 to 20 in.	Plow, disk, and harrow
Va.	3 ft. 6 in. to 4 ft.	1 to 3 plants 8 to 16 in.	Plow often, slightly bedded
N. C.	2 ft. 6 in. to 4 ft.	8 to 12 in.	Plow, fertilize, ridge slightly,
S. C.	3 ft. to 4 ft.	10 to 15 in.	Plow
Ga.	3 ft. to 4 ft.	1 to 3 plants 6 to 12 in.	Bedded
Ky	3 ft. 6 in.	6 to 12 in.	Bedded
Tenn.	3 ft. to 3 ft. 6 in.	12 to 18 in.	Plow and bed
Ala.	3 ft. to 4 ft.	8 to 14 in.	Plow and bed
La.	3 ft.	8 to 10 in. 2 to 5 plants	Bedded
Tex.	3 ft. to 3 ft. 6 in.	9 to 18 in.	Bed in east, low ridge in black land, list in n. west
Okla.	3 ft. 6 in.	8 to 16 in.	
Ark.	3 ft. 6 in.	2 plants 10 to 12 in.	Bedded
N. Mex.	40 in.	10 to 12 in.	Plow
Cal.	3 ft. to 4 ft.	10 to 16 in.	Plow

635. Method of Planting. In nearly all cases cotton is planted in drills with a single-horse planter, although two-horse planters are used in certain sections. Planters usually open up a furrow, drop the seed, and cover them or press them into the soil.

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[18] Mooers, C. A.—"The Effect of Spacing on the Yield of Cotton." *Jour. Amer. Soc. Agron.* Vol. 20, No. 3, pp. 211-230. 1928.

Cotton is generally planted many times as thick as it is expected to stand and thinned with a hoe when the plants are 3 to 5 inches high. From ⅔ to 1 bushel of seed is required per acre. The planters used string the cotton along the row instead of dropping it in hills. The nature of the cotton seed, the fuzz, and the tendency to cling together, makes it impossible to plant untreated seed accurately, as for example to plant a given number of seed per hill. More regular planting is obtained where the seed has been delinted. In a very few cases cotton is planted in hills so that the crop can be cultivated both ways across the field. This reduces the yield and the method is justifiable only in the case of particularly troublesome weeds.

The young cotton seedling is a tender thing and cannot make its way through a thick layer of soil, particularly if a hard crust forms on top. The rule usually followed in planting is to plant barely deep enough to cover the seed. In many cases the seed are not entirely covered. Delinting of cotton seed seems to be a growing practice.

636. Delinting Cotton Seed. Delinting frees the seed of the excess fuzz which, when present, prevents moisture coming into direct contact with the hull. For this reason delinted seed should absorb moisture more rapidly and germinate quicker than ordinary seed.

Collings[19] reports work at the South Carolina station in which delinted seed increased the yield of seed cotton 147 pounds per acre over normal seed. Seven to 9 pounds of concentrated sulphuric acid are used for each bushel of seed. The seed and acid are placed in a wooden tub and after the lint is removed the acid is washed from the seed.

Brown and Gibson[20] state that the advantages of the sulphuric acid treatment of cotton seed are surface sterilization of the seed, hastening of germination, increased percentage of germination, ease in handling the seed during planting operations, and a healthier and more uniform stand.

637. Old Seed. In using old seed care must be exercised, as in some cases 2-year-old seed of certain varieties has germinated only about 5 per cent. Others have obtained as high as 85 to 90 per cent germination from 3-year old seed, and in one test 90 per cent germination was secured with 10-year-old seed.

The use of old seed—seed more than 1 year old—for field planting is sometimes advocated, due to the fact that certain disease organisms do not retain their vitality for more than 1 or 2 years, therefore, if seed 3 years old is used, these organisms would be eliminated. Duggar[21] did not find any consistent gain in the use of old seed.

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[19] Collings, Gilbert H.—*The Production of Cotton*, pp. 61-62. John Wiley and Sons. New York. 1926.

[20] Brown, J. G., and Gibson, Frederick A.—"Machine for Treating Cotton Seed with Sulphuric Acid." *Ariz. Agr. Expt. Sta. Bul. 105.* 1925.

638. Chopping Cotton. When the cotton plants are 3 to 5 inches high, a worker goes over the field with a hoe, chopping out the plants to the desired distance between hills, and at the same operation grass in the row is removed. In case a crust forms on the surface of the ground or grass starts soon after planting, the ground may be harrowed crosswise of the row before the cotton plants come up. If grass comes in the row before the cotton is chopped, the rows may be "barred-off" by the use of either a scraper or a turning plow. After barring-off the row is left on a narrow ridge with the soil removed on either side. The worker doing the chopping then cleans the ridge and blocks the cotton to the desired distance. After chopping, the cotton is back-furrowed or "dirted" by throwing the soil back around the cotton. In case grass or weeds come in, cotton is often hoed one or two times after chopping. Hoeing is expensive tillage and skill is required if speed is to be made. Machines have been devised which block out cotton, but so far none of them have been satisfactory under average conditions. Many which work satisfactorily on level ground, and where a continuous row of plants is available, are not effective where there are "skippy" or thin stands, resulting from unfavorable weather conditions or poor seed. A large part of the work in hoeing and chopping is done by women and children. In general, the subsequent cultivations serve the same purpose and must meet the same requirements as for corn and other crops.

639. Single Stalk Cotton Culture. The essential feature of single stalk cotton culture is the suppression of vegetative branches by delayed thinning until the plants are 10 to 12 inches high. Cook[22] suggested in 1913 that the control of the vegetative branches would permit earlier development of the fruiting branches and result in the production of an earlier crop. This would seem to be an advantage in the presence of the boll weevil or where crop production is limited by a short season, and considerable work has been done testing this idea.

McClelland[23] reports early chopping as yielding 1340 pounds in comparison with 1240 pounds for late chopping, as a 5-year average in Georgia.

Ayres[24] reported similar results from the Arkansas station in

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[21] Duggar, J. F.—"Cotton Experiments." *Ala. Agr. Expt. Sta. Bul. 107*. 1899.

[22] Cook, O. F.—"Results of Cotton Experiments in 1911." *U. S. Dept. Agr. Bur. Plant Indus. Cir. 96*. 1912.

[23] McClelland, C. K.—"Cotton and Corn: Cultural Tests and Variety Tests of 1917 and 1918." *Ga. Agr. Expt. Sta. Bul. 128*. 1919.

[24] Ayres, W. E.—"Cotton Spacing Experiments." *Ark. Agr. Expt. Sta. Bul. 153*. 1918.

1918, and in 1922 from the Delta Branch Station in Mississippi[25] in which early-thinned cotton outyielded late-thinned cotton by 32.4 per cent.

Hall and Armstrong[26] report an increase in yield due to early as compared with late thinning of cotton.

Reynolds[27] reports that normal thinning produced larger yields than late, or deferred, thinning over a period of 3 to 5 years at various stations in Texas.

Meade[28] reports an experiment in which normal-thinned cotton yielded 484 pounds and late-thinned cotton 1071 pounds at San Antonio, Texas; but Brown,[29] in commenting on this and the work of Cardon, states that there is no evidence to show that the gain in yield was due in any way to the late thinning rather than to the close spacing. Brown concludes that the single stalk method of cotton culture is of doubtful value, as there seems to be no experimental evidence to show that increased yields are secured through the late thinning, while there is evidence from 3 experiment stations to show that late thinning most frequently results in lower yields.

Stansel,[30] reporting studies at the Texas Station, states that the results in general show no advantages to be gained in the late thinning of cotton. If, however, through uncontrollable circumstances, cotton must be thinned late, the results indicate that it would be better to leave more plants to the row than is normally the practice. More stunted plants can be left on an acre without crowding than plants which grow normally.

640. Topping Cotton. Topping is supposed to check the vegetative growth and increase the fruiting. In this practice the tip of the main stem or the tips of the stem and the main branches are clipped off a few weeks before the bolls begin opening. Ayres[31] reports the loss of 233 pounds of seed cotton per acre when the plants were topped 50 days after planting and a loss of 93 pounds when topped 60 days after planting.

Some experiments have shown slight increases in the per cent of cotton obtained at the first picking; others showed decreases in this respect. In general, topping cotton has proven detrimental in experimental results.

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[25] Ayres, W. E.—"Cotton Experiments, 1922." Delta Branch Station. *Miss. Agr. Expt. Sta. Bul. 215.* 1923.

[26] Hall, E. E., and Armstrong, Geo. M.—"Cotton Experiments at Florence," *S. C. Agr. Expt. Sta. Bul. 225.* 1926.

[27] Reynolds, E. B.—"The Effect of Spacing on the Yield of Cotton." *Tex. Agr. Expt. Sta. Bul. 340.* 1926.

[28] Meade, Rowland M.—"Single Stalk Cotton Culture at San Antonio." *U. S. Dept. Agr. Dept. Bul. 279.* 1915.

[29] Brown, H. B.—"Cotton Spacing." *Miss. Agr. Expt. Sta. Bul. 212.* 1923.

[30] Stansel, R. H.—"The Effect of Spacing and Time of Thinning on the Yield, Growth, and Fruiting Characteristics of the Cotton Plant in 1925." *Tex. Agr. Expt. Sta. Bul. 360.* 1927.

[31] Ayres, W. E.—"Cotton Experiments, 1921." *Miss. Agr. Expt. Sta. Circ. 42.* 1921.

Ludwig[32] reports an experiment of defoliation of cotton plants, in which he concludes that the yield, both in size and number of bolls, is reduced by defoliation. He found also that defoliation delayed maturity rather than hastened it. The earlier at which defoliation occurred before the ripening of the crop, the greater the deleterious action.

641. Labor Requirement in Growing the Cotton Crop. The United States Department of Agriculture[33] reports the labor required per acre in the different operations involved in growing the cotton crop and bringing it to harvest, particularly in the states of Georgia, Alabama, and Texas.

641a. Crew (man and horse) required in different operations in cotton production and the acres covered per day in different sections.

LOCALITY	OPERATION	CREW		RATE IN ACRES PER 10-HOUR DAY
		Man	Horses	
Georgia	Cutting stalks	1	2	7.7
Alabama	Cutting stalks	1	2	7.1
Texas	Cutting stalks	1	2	8.3
Georgia	Lay off rows	1	1.2	5.6
Alabama	Lay off rows	1	1.2	5.0
Texas	Lay off rows	1	1.2	7.1
Georgia	Drag or smooth	1	1.8	7.1
Alabama	Drag or smooth	1	1.8	5.9
Texas	Drag or smooth	1	2.7	20.0
Georgia	Bed and rebed	1	1.1	3.8
Alabama	Bed and rebed	1	1	2.1
Texas	Bed and rebed	1	3.9	6.7
Louisiana	Bedding with middle buster	1	2	5.9
	Bedding with a turning plow	1	1	2.84
	Bedding with a turning plow	1	2	3.4
Georgia	Planting—1-row planter	1	1	6.7
Alabama	Planting—1-row planter	1	1	5.0
Texas	Planting—1-row planter	1	1.1	6.7
General U. S.	Planting—1-row planter	1	1	7.1
General U. S.	Planting—2-row planter	1	2	14.1
General U. S.	Planting—by hand in rows	1	0	4.6
Georgia	Chopping	1	0	1.1
Alabama	Chopping	1	0	.7
Texas	Chopping	1	0	1.3
Georgia	Hoeing	1	0	1.4
Alabama	Hoeing	1	0	.9
Texas	Hoeing	1	0	2.4

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[32] Ludwig, C. A.—"Some Effects of Late Defoliation on Cotton." *S. C. Agr. Expt. Sta. Bul. 238.* 1927.

[33] *U. S. Dept. Agr. Yearbook 1922,* pp. 1063-1065.

The operations on cultivation have been given. See Table *292a.*

642. Harvesting the Crop. Cotton is generally picked by hand. Men, women, and children do the work. The equipment for cotton picking is usually a cotton sack varying in length from 3 to 9 or 12 feet and about 28 inches wide. The sack is dragged on the ground, supported by means of a strap which goes over the shoulder, causing the sack to hang in a loop at one side of the picker. The picker grabs or snatches each boll of cotton and when he has 4 or 5 bolls in each hand, he puts them together and throws them with a backward swing into the sack. Considerable skill is required in picking cotton, and men who have not picked cotton before do well to get 65 to 75 pounds of seed cotton in a day, while a skilled picker can easily pick 225 pounds. The amount of cotton picked in a day by different workers and under different conditions varies from 100 to as high as 500 pounds; 150 pounds to 250 pounds is considered a fair day's work. The number of pounds picked by each worker is definitely known, giving an element of competition which is stimulating. The payment for cotton picking is always made on the basis of the number of pounds picked. The price paid per 100 pounds varies somewhat with the price of cotton. The average price paid is probably between 75 cents to $1.00 per hundred in the early part of the season, and a higher price, varying from $2.00 to as high as $3.00 to $3.50 per hundred, in the western part of the cotton belt, in the latter part of the season when the weather is disagreeable and less cotton can be picked per day. Cotton picked from the field is weighed as it is emptied from the sack, often into a wagon equipped with cotton sideboards, or placed in large piles on the ground, or in certain cases stored in cotton houses.

All the bolls on a stalk do not ripen at the same time, making it necessary to go over the field 2 or 3 times during the season. The date of picking depends upon the climatic conditions. In the southern part of the cotton belt picking starts early in August and is completed in November or December. In certain years picking is continued throughout the winter.

Egyptian and Sea Island cotton are more difficult to pick than the ordinary grades as the bolls are small and do not open in the same way. Also the grade of cotton must be more carefully guarded; leaves and trash must be carefully removed. Sea Island cotton is usually picked over after being gathered from the field and all leaves and trash removed.

In the northern part of the cotton belt frost kills the cotton before the end of its normal season of growth while the bolls are only partially open. It is the common practice in this section to gather, or snap, or pull these bolls in the fall; they are then picked at the gin with a huller attachment. The cotton so obtained is called bolly cotton and receives a low price on the market.

643. Picked and Snapped Cotton. In some sections considerable cotton is "snapped" in the field instead of being picked, because of interrupted maturity or because untrained workers can harvest the cotton more quickly in this way. Willis [34] reports spinning tests with cotton picked and snapped in the same fields in Texas and Oklahoma. The results indicate that the snapping of cotton lowered the quality about 2 grades, but that the spinning quality of the lint was not noticeably affected. The waste in the snapped cotton was not materially greater than in picked cotton of equal grade.

644. Mechanical Cotton Pickers. A considerable number of different machines have been devised for picking cotton, but none of them have been outstandingly successful. In general, 3 types of mechanical pickers have been put on the market. These are: the vacuum type which gathers the cotton by suction; the mechanical finger type which removes the cotton from the plants by means of hooked disks when the fingers are brought into contact with the cotton; and the whirling spindle type in which mechanical spinning fingers are brought in laterally to all parts of the cotton plant and the whirling motion of fingers coming in contact with the boll pulls the lint from the boll. One of the most successful of these machines has picked a bale of cotton in 3 hours.

In the extreme western part of the cotton belt a sled type of picker is used. In this section, cotton may be left on the plants until practically all the bolls are ripe and the leaves have fallen, making it possible to simply drive a stripper over each row stripping the bolls from the plants. The bolls and trash are separated at the gin by means of a hulling attachment. In the eastern portion of the cotton belt many of the smaller farms average only 20 to 30 acres, while in the western part of the cotton belt one man may tend many times this acreage, due to the fact that hand labor is largely eliminated both in cultivation and in harvest. In this way although the grade of cotton produced is perhaps slightly lower, the amount of cotton produced per man is greatly increased.

645. Cotton Ginning. In the greater part of the United States, cotton is ginned in what is called a saw gin. The modern saw ginnery contains from 2 to 8 gins or gin stands, as they are commonly called. These are usually arranged in 2 parallel rows. In the ginning process the seed cotton is lifted from the grower's wagon by suction and carried mechanically through the cleaner, distributor, and feeder to the saws. The saws which revolve at a high rate of speed are steel disks 10 to 12 inches in diameter with sharp teeth at the outer circumference. As the cotton is delivered to these saws, the teeth catch the cotton lint and pull it between guards which are too narrow to let the cotton seed through. At the back of the saws are brushes, revolving more rapidly than the saws, which brush the lint from the saw teeth. Various cleaning processes are used in handling the cotton from the gin stand or gin saws. From the saw the lint is carried by a current of air to condensers, where it is dropped into the press box. Here it is packed by mechanical tampers and pressed into a bale.

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[34] Willis, H. H.—"Spinning Tests of Picked and Snapped Cotton." *U. S. Dept. Agr. Bur. Agr. Ex. 1926*, p. 18. 1926.

A load of 1500 pounds of seed cotton will usually yield about 500 pounds of lint,—or a bale—, and between 900 and 1000 pounds of seed, the rest of the 1500 pounds being dirt. As a load of cotton is picked it is hauled direct to the gin. As it is ginned each man's seed as well as his lint is kept separate from that of others and when he drives away from the gin he usually takes his seed and bale of cotton with him. Cotton is usually baled into flat or square bales, the bale being about 27 inches thick, 54 inches long, and of varying widths,—usually about 45 inches.

Another type of bale is the round bale. The round bale of cotton is about 20 to 25 inches in diameter and 35 inches in length and weighs about 250 pounds. It is not tied but is enclosed in burlap bagging. A lint sample of cotton is taken at the time the round bale is made and the covering of the bale is not afterward cut for sampling. When cotton is to be shipped some distance the regular bales are put through a compress, where the size is considerably reduced.

646. Roller Gins. Another type of gin is known as the Roller gin, the essential parts of which are a roller covered with leather of such a texture that the fibers of the cotton will cling to it freely, and a "knife" blade, set so that the edge is parallel to the surface of the roller and barely touches it. The lint is caught by the rapidly revolving roller and stripped from the seed which are held back by the knife. The use of this type of gin in this country has been confined largely to the ginning of long staple cotton, particularly Sea Island and American Egyptian cotton. The roller gin is much slower than the saw gin.

647. Cotton Seed. Cotton seed at one time was considered largely a waste product, but it is at present among the main assets of the South. All parts of the seed are now being used,—the lint, the fuzz, the hulls, the oil, and the meat or meal part. Brown and Anders[35] have reported the analysis of the seed of a large number of different varieties of cotton. The per cent of meat or kernel varied from 51.7 to 59.2 per cent; the hull from 40.8 to 48.3 per cent, and the moisture content from 6.8 to 8.2 per cent. The per cent of oil in the kernel varied from 31.9 to 36.6, and in the seed from 17.0 to 21.7 The per cent of ammonia in the seed varied from 3.4 to 4.0. The oil yield per ton of clean seed was from 37.5 to 50.1 gallons and the cake yield from 965.7 to 1131.4 pounds. The percentage of lint from these different varieties varied from 28.0 to 38.4.

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[35] Brown, H. B., and Anders, C. B.—"Cotton Experiments, 1919 and 1920." *Miss. Agr. Expt. Sta. Bul. 187*. 1920.

Creswell and Bidwell [36] report more than 50,000 analyses of seed made during the period 1916 to 1919, in which the oil content per ton averaged 306 pounds, the range being from 284 pounds in Texas and Oklahoma to 322 in Mississippi. They found that varieties with the longest staple had the highest oil content; also that larger seeded varieties and those with a high percentage of protein had a low oil content.

About 80 per cent of the cotton seed of the South is crushed for making oil and other by-products, while the remaining 20 per cent is generally used for feed. When the seed come to the mill they are first cleaned of trash and then passed through a delinting machine which removes a considerable part of the fuzz clinging to them. From the delinting machines they are carried to a machine known as a huller, which separates the hulls from the meat or kernels. The clean kernels next pass through a series of rollers which crush the seed so that each cell is ruptured. In the next step the crushed kernels are subjected to a temperature starting at 140 degrees and gradually increasing to 220 degrees F. From the cooker the material is pressed into cakes at a limited pressure, these cakes then going into the hydraulic presses which remove as much of the oil as possible. From these presses the oil is filtered and is ready for shipment to refineries. Cotton seed oil has many uses; it is used in the manufacture of oleomargarine, lard substitutes, salad and cooking oils, emulsions for medical purposes, soap, cosmetics, washing powder, linoleum, oilcloth, and as a cheap paint base, as well as in numerous other products. The material remaining after the oil has been removed is known as cotton seed cake, which is recognized as of such high value as a concentrate in feeding livestock that the value of many other feeds is measured by comparison with it. The cotton seed cake is usually ground into meal before it is offered on the market.

Sheets and Thompson [37] state that from a ton of cotton seed 303 pounds of crude oil is obtained, 954 pounds of cake or meal, 514 pounds of hull, and 110 pounds of linters or coarse fiber with an average loss of 119 pounds in the process of manufacture.

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[36] Creswell, Charles F., and Bidwell, George L.—"Composition of Cotton Seed." *U. S. Dept. Agr. Dept. Bul. 948*. 1921.

[37] Sheets, E. W., and Thompson, E. H.—"Feeding Cotton Seed Products to Livestock." *U. S. Dept. Agr. Farmers' Bul. 1179*. 1920.

648. By-Products. The linters are used in making pads, comforts, cushions, horse collars, mattresses, and also in general upholstery work. The wadding is mixed with wool in hat making and in making fleece-lined garments. It is also used for low grade yarns, carpets, cellulose, writing paper, varnishes and celluloid as well as in many other ways. The hulls are used for feed, fertilizer, fuel, and packing.

STUDY QUESTIONS ON CHAPTER XXII

1. With what countries does the United States compete in the production of cotton?
2. Where or in what way may increases in cotton production in the United States be brought about?
3. Describe the cotton plant, briefly, giving such information as would make it possible for one wholly unfamiliar with cotton to recognize it.
4. What is the nature of the cotton lint? What character gives it value for spinning?
5. What precautions are necessary in order to keep a strain of cotton pure?
6. How would you proceed to secure the best strain of cotton for your community?
7. What causes "shedding" of cotton?
8. Why are the methods of seedbed preparation for cotton usually considered poorer than for other crops? How would you prepare the seedbed for cotton?
9. In growing cotton what determines the best spacing and width of rows? How does the presence of the boll-weevil influence this?
10. What effect does close spacing have on the time of maturity? On the size of plants? On the length of the flowering period?
11. What preparation of the seed before planting would you advise? How would you plant?
12. Outline the operations necessary after planting in caring for a field of cotton.
13. What is the aim and how effective is the single-stalk method of growing cotton?
14. Outline the steps in harvesting, ginning, and marketing a crop of cotton.
15. Make a chart showing the uses of cotton seed.

APPLICATION ASSIGNMENTS ON CHAPTER XXII

1. Assume that the cotton crop was short last year and that the crop averaged 21 cents per pound. You have an opportunity to double your acreage the coming season. What statistics, both foreign and domestic, would influence your decision?

2. Part of your cotton land is rolling upland and part flat, rich, river bottom, in central Mississippi. Select a type and variety of cotton for each portion of your land. Tell why you make these selections.
3. You observed a stalk of cotton heavily laden with an early crop of bolls and so much superior to others which surround it that you decide to try to develop a variety from it. Tell definitely what you will do each year, both to test the result and to maintain the type.
4. You notice that during alternating hot and wet weather the cotton squares are falling in large numbers as they are formed. What will you do? Why?
5. Your cotton is to be planted next year on corn ground from which the stalks were harvested for fodder. When will you plow? How deep? Why?
6. You are ready to plant cotton on a sandy loam soil 10 days before the usual planting time. Will you plant now or wait? Why? You are not ready to plant until 10 days after the regular time. Will you modify your methods? Why?
7. You have found that on an average soil your cotton does best in rows spaced three feet six inches apart. You are planting this year on a much more fertile soil, well supplied with moisture. What changes will you make in planting?
8. You are inexperienced in cotton production. You have been told that you can delint cotton seed and plant so accurately that you can eliminate chopping. Will you plan to do this? Why?
9. You are not sure of the purity of the cotton seed returned to you from the gin. You have a good strain with which you are anxious to continue. You have some seed carried over two seasons. What will you plant? Why?
10. On a sandy loam upland of average fertility you have a heavy stand of cotton ready for chopping. What instructions will you give your help? Why?
11. Your cotton is on rich bottom land. What instructions will you give the choppers? Why?
12. Your cotton, on rich bottom land, is making a very large top growth. You are anxious for it to mature early and are told to cut the tops out. Will you do so? Why?
13. You are growing cotton on Mississippi river bottom soil. A neighbor, recently from west Texas, tells you enthusiastically of harvesting cotton with sleds. He wants you and others to practice this method and change the equipment of the local gin to take care of cotton harvested in this way. Will you change? Why?
14. You are to speak at a local farmers' meeting on "The Mechanical Cotton Picker." Write your speech, stressing the need, the difficulties and the promising developments.
15. You are ready to go to the gin when rain wets the upper half of your load. What will you do? Why?
16. You are growing long staple cotton and may go either to a roller or to a saw gin. Which will you use? Why?
17. Cotton seed is $30.00 per ton. You can feed it or use it for fertilizer. What will you do? Why?

CHAPTER XXIII

TOBACCO AND SUGAR BEETS

TOBACCO

Tobacco is native to America where it was being cultivated and used by the Indians when the continent was first visited by European explorers. Settlers in Virginia and Maryland immediately took up the growing of the crop and it soon became a leading article of exchange with England. (Figure 26.)

The tobacco crop ranks seventh in value in the United States, exceeding both rye and barley, which are grown on larger acreages. Kentucky produces about a third of the total crop and North Carolina and Virginia combined, another third. The five leading countries in order of quantity production are the United States, India, Russia, the Dutch East Indies, and Japan. The average acreage in the United States for 1917 to 1921 is reported as 1,700,000 acres. The average production for this period was about 800 pounds per acre.

649. The Tobacco Plant. The tobacco plant is a rank growing annual, with a simple cylindrical stem varying from 4 to 8 feet in height and with the leaves arranged alternately, arising directly from the central stem. The leaf is an extremely broad, elongated structure often a foot in width and 3 feet in length. The leaves are covered with a soft, downy glandular pubescence, which makes the surface somewhat sticky. The plant has a tap root system from which lateral roots, though somewhat limited in extent and range, spread in all directions. The flowers are pink or rose colored and are borne in panicles at the top of the plant. Normally, the plant is self-fertilized but cross-fertilization is easily effected by insects. Each flower has a long corolla tube. The seeds are borne in large capsules, many seeds being borne in each capsule.

650. Classification and Types of Tobacco. The botanical name of tobacco is *Nicotiana tabacum* (Linn). It belongs to the order *Solanaceae*. Garner *et al.*[1] describe 4 general types of tobacco: (1) dark fire-cured and air-cured, (2) bright flue-cured tobacco, (3) leaf tobacco, and (4) burley tobacco. The dark fire-cured or air-cured type of today is fundamentally the same as the original Jamestown tobacco.

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[1] Garner, W. W., *et al.*—"History and Status of Tobacco Culture." *U. S. Dept. Agr. Yearbook 1922.*

The Indians taught the settlers how to use open fires to cure green tobacco and this method of curing together with certain cultural practices learned from the Indians is still followed.

The important centers of dark fire-cured and air-cured tobacco production are in Kentucky, Virginia and North Carolina; bright flue-cured in South Carolina and Georgia; cigar leaf in Wisconsin, Ohio, Pennsylvania, and Connecticut; and Burley in northern Kentucky, southwest Ohio and western West Virginia. Each type of tobacco has its special requirements as to soil and climate and the present localization of production of the different types is the result of a long process of evolution and specialization.

The type and condition of the soil and the climate probably affect the quality in tobacco to a greater extent than any other crop grown. Light sandy and sandy loam soils, because of low water holding capacity and low soluble mineral matter, tend to produce a light leaf of relatively large size, light in color and body, fine in texture, and weak in aroma. Heavier soils containing more silt and clay tend to produce a leaf of small size, dark color, heavy body, and strong aroma. In the Connecticut valley and in Florida, cigar wrapper and binder types are grown on sandy and sandy loam soils containing but little clay. In Pennsylvania and Ohio the soils used for growing filler are heavier and have a higher water-holding capacity than the binder leaf types. Burley tobacco obtains its highest development on highly fertile, phosphatic limestone soils of the bluegrass regions of Kentucky and Ohio. Dark fire-cured and air-cured tobacco are grown on heavy silt and clay loams with a high water-holding capacity, while cigarette types and granular types of smoking tobacco are grown mainly on the lighter soils having but little clay in the subsoil. Filler and wrapper grades are obtained on somewhat heavier soils with more clay in the subsoil.

651. Manuring and Fertilizing. For all types of tobacco except the flue-cured or bright tobacco, heavy applications of barnyard manure may be plowed into the soil. Wisconsin recommends about 20 tons of barnyard manure per acre; also, either super-phosphate manure or complete fertilizer with the barnyard. Pennsylvania recommends the application of stable manure at the rate of about 10 loads per acre.

Garner[2] recommends the application of 2000 pounds of a 5-5-6 fertilizer for cigar tobacco, on land which has been well manured. On land which had not been manured he recommends the same amount of a 6-5-6 fertilizer.

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[2] Garner, W. W.—"Tobacco Culture." *U. S. Dept. Agr. Farmers' Bul. 571.* 1914.

652. Seeding Tobacco in Beds. Tobacco is usually seeded in beds 6 to 12 weeks before time to set the plants in the field. A cold frame or a hot bed may be used. If the climate permits, a sunny exposure may be used for this bed. The bed is usually sterilized in some way to a depth of 2 or 3 inches before planting the seed in order to kill the weed seed and diseases which may be in the soil. A seedbed soil which does not bake and which contains a large amount of organic matter is desirable.

In general, the recommendations for seeding are to use a level teaspoonful of seed for 100 square feet of bed. Because the seed are so small they are usually mixed with some other light colored material and sown, the entire bed being gone over several times to get an even distribution. The seed are raked in lightly and the surface either rolled lightly or packed. The bed is then covered with cheese cloth or with glass and kept moist.

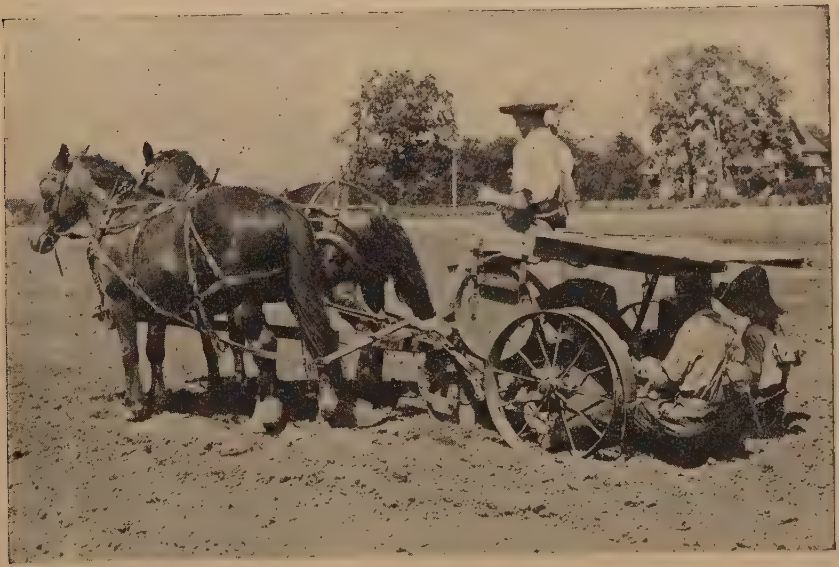

FIG. 117.—Transplanting tobacco plants to the field.

653. Field Planting. Frear and Hibshman[3] state that when plants have grown to a height of 5 to 6 inches with 5 to 7 leaves they have reached the best stage for transplanting.

It is desirable to have the plants at the proper stage of maturity so that they can be transplanted in the field as soon after the last killing frost as possible. Shallow cultivation is given the crop in order to keep out weeds. The same principles of cultivation apply to tobacco as to corn.

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[3] Frear, William, and Hibshman, E. K.—"The Production of Cigar Leaf Tobacco in Pennsylvania." *U. S. Dept. Agr. Farmers' Bul. 416.* 1910.

Fields for planting tobacco should be plowed and worked thoroughly so that at the time of transplanting they will be in good tilth. The field is usually marked off with a marker before the time for transplanting and the plants either set by machine or by hand. The rows vary from 3½ to 4 feet apart, with the plants spaced 14 to 28 inches in the row.

A very high quality wrapper leaf tobacco is grown in Connecticut under shade made from cheesecloth.

654. Topping and Suckering. In the operation of topping, half of the plant is broken out. Kentucky[4] recommends that 14 to 18 leaves be left on burley plants when topped and 10 to 14 on the dark tobacco types.

The general recommendations are that tobacco should be topped before the first blossoms open. The proper height to top and the number of leaves to be left depend upon the fertility of the soil and the variety or type of tobacco grown, also upon general climatic conditions. The later in the season topping is done, usually the lower the plant will be topped as topping plants low hastens maturity. When the tops are broken out of the plant the buds in the axis of the leaves start development, producing suckers which are removed as soon as they are large enough to be pulled. It may be necessary to remove the suckers 2 or 3 times.

Selby and Houser[5] report a gain of $36.00 per acre as a two-year average for suckering tobacco. Suckering 1 week before cutting gave an increase of $12.35 over suckering just before cutting time. Suckering twice gave a gain of $20.07, while suckering 3 times gave a gain of $24.53.

655. Harvesting Tobacco. One method of harvesting tobacco is to pick off each leaf as it matures, in which case the leaves are shed cured, stringing them on wires or nails. However, the more usual method of harvesting is to cut the entire plant off near the ground and hang it in the field, top down, until well wilted, when it is carried to the curing shed. The proper stage of harvesting is indicated by a change from dark green to a lighter shade, the leaves taking on a mottled appearance. Thickening of the leaf, a leathery feeling and snapping, or breaking, of the leaf when creased are other tests made to determine the proper stage for harvesting. The lower leaves will be dead ripe while the upper leaves are still green. Growers try to pick an average time at which the central leaves on the plant are just about mature.

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[4] Scherffins, W. H., and Woosley, H.—"Tobacco." *Ky. Agr. Expt. Sta. Bul. 139.* 1909.

[5] Selby, A. D., and Houser, True—"Tobacco Culture in Ohio." *Ohio Agr. Expt. Sta. Bul. 238.* 1912.

656. Curing. Large sheds with a means of controlling the ventilation are usually used for curing tobacco. The air curing requires several weeks if weather is unfavorable. In damp weather the ventilators are closed, while if the air is dry the ventilators are kept open both day and night. In open fire-curing the tobacco plant may be allowed to cure in the field for a somewhat longer period than when other methods are used. The tobacco is cured in the shed with a slow fire, the temperature being gradually increased as the curing progresses. In flue-curing, furnaces are used where the hot air pipes are carried through the building in which the tobacco is kept. This is the most rapid process of curing, the process often being completed in 3 days. The open-fire method requires approximately 10 days, while air-curing varies widely with the weather conditions.

The curing of tobacco is not a simple drying process as the green leaves of tobacco, like other plant material, may heat, injuring the quality; particularly if the moisture content is high in the air of the shed or if the leaves are in contact with each other.

657. Stripping and Packing. When the plants have been cured out, the next process is stripping. The leaves are allowed to become moist by the absorption of moisture from the air or by artificial means such as the use of dampening cellars, steam, or sprinkling the butts of the plant. In the stripping process the leaves are removed from the stem of the plant, sorted into grades of like quality and tied into hands or bundles. A "hand" is merely a bunch of leaves tied together, usually with another leaf. It is in this form that tobacco goes to the market. In some sections the leaves after stripping are packed evenly and tightly into packing boxes, the tips of the leaves overlapping sufficiently to hold the bundles together.

Sugar Beets

The sugar beet is a comparatively new crop in the United States. Germany at the present time is the leading country in the production of these beets, followed in order by Czecho-Slovakia and Russia with the United States ranking fourth. Other countries in order of production are: France, Poland, Netherlands, Belgium, Spain, and Italy.

658. History. Harris[6] states that the early history of sugar beet culture is not known though 2 varieties were described as early as 300 B.C. Marggraf, a German chemist, in 1747 was the first to obtain sugar from the beet.

The early history of the beet and sugar manufacturing is of interest. Ackard, a student of Marggraf, was the first to develop a practical method of extracting the sugar, which he presented to the Institute of France, and a committee of leading scientists was appointed to look into the matter. Various means were taken by those interested in other sugars to destroy the interest in beet sugar. Claims were made that while sugar could be made from beets, it was too sour for food. However, soon after 1806, Napoleon encouraged sugar beet manufacture in France and set aside large tracts of land to be devoted to beet raising, requiring the peasants to plant the land to this crop. Forty factories were in operation by 1812, with over 3,000,000 pounds of sugar produced. With the downfall of Napoleon in 1815, the importation of cane sugar was again allowed with the result that only one factory survived. Legislation fluctuated, sometimes favorable to beet and sometimes to cane sugar; and the industry fluctuated accordingly. In Germany the legislation was more consistent and the industry grew steadily.

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[6] Harris, F. S.—*The Sugar Beet in America*, pp. 8-20. The Macmillan Company. New York. 1919.

In the United States the first successful factory was erected in Alvarado, California, in 1879. Here legislation has at times been favorable and at times unfavorable to this crop and the well-being of the industry has fluctuated accordingly. (Figure 27.)

659. Classification and Description. The sugar beet belongs to the goosefoot family (*Chenopodiaceae*). Spinach is the only other important cultivated plant of this group, though pigweed, lamb's quarter, and Russian thistle also belong to this family. The botanical name for the sugar beet is *Beta vulgaris*, which includes sugar beets, mangels, and common garden beets. The sugar beet is ordinarily a biennial, storing food in the roots the first year and in the second year sending up seed stalks which are from 2 to 4 feet tall. The sugar beet has a large tap root which gradually tapers into a relatively small root. The percentage of sugar in the beet is lowest at the extreme tip and the extreme top, the maximum amount of sugar being found in the outside layers about one-third the way down the beet from the crown.

660. Culture of Sugar Beets. In general, the soils recommended for sugar beets are fertile, deep, and of a texture which is easy to work. Almost any good corn soil is suitable. The seedbed preparation for planting is much the same as for corn but deeper and with the soil worked into a somewhat finer, more mellow seedbed. Sugar beets remove rather large quantities of potash. A normal crop of sugar beets of 10 tons removes 35 pounds of nitrogen, 70 pounds of potash, and 14 pounds of phosphoric acid, while a 40-bushel yield of corn removes 56 pounds of nitrogen, 23 pounds of potash, and 21 pounds of phosphoric acid.

Sugar beet seed is quite often furnished to the growers by the factory which is contracting for the crop. Seed is very important in the case of sugar beets as a poor quality of seed, from the standpoint of breeding, may produce a large yield but not be desirable from the standpoint of sugar content.

In general, the recommendations are that planting should be done as soon as the soil is warm and dry enough to insure quick germination. The amount of seed to be used per acre varies from 12 to 25 pounds, with 15 to 20 pounds the usual amount. The seed are drilled in rows, varying from 18 to 24 or 28 inches apart, with 20, 22, or 24 inches usually recommended.

FIG. 118.—An Iowa sugar beet field in August. *What factors determine the advisability of growing sugar beets as a commercial venture on any particular farm?*

661. Blocking and Thinning Beets. From the time the beets are up until the crop is harvested a large amount of hand work is required in the beet field. The sugar beet company quite generally hires labor on contract to do this work. It is important to have a uniform stand of beets and but one beet in a place. The nature of the beet seed, with 3 or 4 seed per seed ball, makes it necessary that this thinning should be done by hand, and this is usually done when the plants have about 4 leaves. Greater damage is done by delayed rather than by early thinning, however. The first operation in thinning is to block out a row much as cotton is chopped, leaving a bunch of plants at the desired distance apart. These plants are then thinned down until only the best plant in each clump is left, by pulling out the others by hand. Beets are usually spaced from 8 to 12 inches apart in the row. From the time the beets are thinned until harvest the crop is hand hoed as much as may be necessary to keep it free of weeds.

Shaw[7] reports a study in which it was found that the loss in stand in sugar beet culture resulting from the use of poor germinating seed was 19.32 per cent; to improper spacing and thinning, 27.3 per cent; losses occurring between thinning and harvesting, 7.26 per cent. An average of all these losses made a loss of more than 50 per cent in stand. The yield of the crop was closely related to stand.

662. Harvesting Beets. The operations of harvesting beets are pulling and topping. The beets are first raised in the row and the roots broken loose with a double-pointed implement resembling a two-pointed plow or by means of a slide lifter, which is a small shoe or plow on the end of a long shank, after which the beets are pulled by hand and thrown into piles. A heavy knife is usually used in cutting off the top at the lowest leaf scar. The topped beets are piled on the ground ready for hauling; the piles are usually covered with the tops to prevent evaporation. As soon as possible after topping the beets are hauled in special wagons to the shipping point. If cars are not available the beets are hauled to the shipping point and piled in large piles on the ground. The yields of sugar beets range from 5 to 20 tons per acre with the average for the United States approximately 10 tons.

STUDY QUESTIONS ON CHAPTER XXIII

1. State the relative importance and give the history of tobacco production in America.
2. Where are the different types of tobacco grown and in what form are they used?
3. Give instructions for growing a crop of tobacco.
4. How does the acreage of tobacco per man compare with that of corn and cotton in their respective belts? Why?
5. Outline the operations and give the reasons for each, in the curing and preparing of tobacco for market.
6. What are the conditions which at times have made the sugar beet industry so uncertain?
7. Give instructions for growing a crop of sugar beets.
8. How does the acreage of sugar beets per farm compare with that of wheat and cotton in their respective belts? Why?

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[7] Shaw, H. B.—"Sugar Beets. Preventable Losses in Culture." *U. S. Dept. Agr. Dept. Bul. 238.* 1915.

9. What are the methods which have been used in increasing the sugar content of the beet crop?

APPLICATION ASSIGNMENTS ON CHAPTER XXIII

1. You have purchased an 80-acre farm in the tobacco section of Kentucky. You expect to grow tobacco. What other crops will you produce? Outline your cropping plans, the type of tobacco you will grow, the equipment and buildings you will need, and the methods you will use in handling the crop.
2. A sugar factory has been erected 8 miles from your farm. You are offered a contract on 40 acres of beets at a good price with a bonus for high sugar content. Labor will be furnished at a reasonable figure. What considerations will influence your decision?
3. You decide to grow sugar beets. Your soil is a medium black loam. You have 40 acres fall-plowed six inches deep and 40 acres in corn stalks to be plowed in the spring. Which field will you plant to beets? How will you put in the crop?
4. Your beets are still growing nicely when an early frost kills the tops. What will you do? Why?
5. You find that you can dig beets much faster than they can be hauled. You have three-quarters of your crop dug and only one-quarter hauled. You are afraid of unfavorable weather. What will you do? Why?

CHAPTER XXIV

FORAGE CROPS

The proportion of arable land devoted to forage crops varies widely in different parts of the world. About 1/6 of the arable land of the United States was used for temporary meadows and other fodder crops in 1925. This classification includes the tame hay crops, small grains cut for hay, and corn used for ensilage or for fodder or hogged off, but excludes wild hay. Similar comparisons show that 1/6 of the arable land also is devoted to forage crops in Italy, Hungary, Austria, and Germany; in Australia, 1/15; in the Union of South Africa, 1/10; in India, 1/32; in Spain, 1/16; in Chile and Argentine, 1/3; while in Great Britain and France practically 1/2 of the arable land is used for the production of forage.[1]

Most of the crops grown for forage are either grasses or legumes, though a few of the minor forage crops, such as rape, kale, turnips, mangels, rutabagas and sunflowers do not belong to either of these families.

663. The Ideal Forage Plant. Forage crops may be grown either in rows and cultivated or seeded broadcast and harvested and cured for hay; seeded solid or in rows and fed off by grazing, or even cut and fed green. In general, it may be said that the ideal forage plant, in addition to the capacity to give satisfactory yields of nutritive and palatable food, must be possessed of good reproductive characters such as abundant and easily gathered seed and must be aggressive; that is, it must be able to maintain itself under conditions of competition. When used for pasture it must also be able to recover rapidly after being eaten off by animals. For pasture purposes, many of the grasses are of the greatest importance. The growing point in the grasses is at the base of the leaf, so that the ends may be eaten off and growth continue uninterrupted. With a good many crops where the growth is terminal, as in most legumes, the growing points are the first to be eaten by pasturing animals and such crops are not as ideal for pasture.

664. Importance of Crop Plants Harvested as Forage. Data presented by Piper *et al.*[2] give an idea of the relative importance in livestock production of the principal crop plants producing harvested forage in the United States for 1919.

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[1] Internatl. Inst. Agr. (Rome)—*Internatl. Yearbook Agr. Statis. 1925-26*, pp. 20-100.

[2] Piper, C. V., *et al.*—"Our Forage Resources." *U. S. Dept. Agr. Yearbook 1923*, p. 342.

664a. Relative importance in livestock production of the principal crop plants, producing harvested forage.

Crop Plant	Animal Units Each Item Would Theoretically Support for One Year
1. Corn	27,608,000
2. Oats	6,240,000
3. Alfalfa	3,771,000
4. Clover	3,364,000
5. Timothy	3,184,000
6. Wheat	2,914,000
7. Wild or native grasses	1,954,000
8. Sorghums and sugar cane	1,665,000
9. Barley	819,000
10. Miscellaneous tame grasses	800,000
11. Cotton	556,000
12. Cowpeas	390,000
13. Peanuts	295,000
14. Rye	230,000
15. Velvet beans	204,000
16. Sugar beets	144,000
17. Flax	119,000
18. Mixed grains	116,000
19. Soybeans	100,000
20. Field beans	100,000
21. Field peas	43,000
22. Rice	40,000
23. Potatoes	40,000
24. Sweet potatoes	28,000
25. Emmer and spelt	25,000
26. Roots	19,000
27. Canning peas	12,000
28. Vetch	9,000
29. Hay (imported)	24,000
Total	54,813,000

665. Cultural Practices. Method, rate, and date of seeding forage crops, seedbed preparation and other specific cultural operations are considered under the specific crops. Therefore, it is necessary to include here only such material as is applicable to forage crops in general.

Forage crops are usually harvested either as hay, as silage or fodder, or as pasture. The harvesting of crops for silage and as fodder has been considered in previous chapters, so that it will be necessary to discuss here only harvesting as hay and as pasture.

666. The Maturity Factor in Hay Making. Fine stemmed grasses and legumes used for forage crops are usually cut for hay at a stage when they can be most satisfactorily cured. One also wants the greatest total yield with the least injury to the stand in cutting, the largest degree of palatability of the material and the greatest amount of digestible substances. There is no stage in the maturity of a specific plant when all of these can be had to the fullest degree. Therefore, to get a product which is the best that it is practical to produce something of the development of the different crop plants must be known. This has been indicated somewhat in the discussion of corn and of the sorghums; the smaller grass plants behave in a somewhat similar way at corresponding stages of maturity. In general, in both the legumes and the grasses, the per cent of ash and of crude protein decrease while the crude fiber and the nitrogen free extract increase as maturity is approached. Because of the increase in the total production of dry matter per acre as maturity is approached there is usually more of each of the feeding constituents at or near maturity than at earlier stages. Table *666a* presents the water-free analysis of Sudan grass, of timothy, and of alfalfa at two stages of maturity.

FIG. 119.—Pigs on alfalfa pasture. *Alfalfa has often been referred to as the ideal forage plant. Having in mind a particular locality what is the value of the average acre of alfalfa when pastured with hogs and when made into hay and fed to dairy cattle?*

The Illinois Station[3] reports the composition at different growth stages of timothy and Kentucky blue grass, also of red and mammoth clover. (See Table *666b*.)

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[3] Hunt, Thomas F.—"Grasses and Clovers: Effect of Ripeness on Yield and Composition." *Ill. Agr. Expt. Sta. Bul. 5.* 1889.

666a. Maturity as effecting composition of Sudan grass, timothy, and alfalfa. Figures in per cent. Summary.

Yrs.	Crop and Stage of Maturity	Ash	Ether Extract	Protein	Crude Fiber	Nitrogen Free Extract
	Sudan grass, just before heading[a]	9.26	1.98	12.89	27.05	48.82
	Sudan grass, seed fully mature[a] ..	7.35	1.38	6.03	36.71	48.53
3	Timothy, just coming into bloom[b]	6.57	3.34	7.74	34.37	47.99
5	Timothy, seed fully ripe[b]	5.53	2.79	5.82	34.87	51.00
	Alfalfa, cut in the bud stage[c] ...	10.62	2.36	19.65	22.50	35.06
	Alfalfa, cut in the seed stage[c] ...	7.53	3.34	14.98	26.52	37.36

[a] Call, L. E., and Fitch, J. B. "Sudan Grass as a Supplementary Pasture Crop for Dairy Cattle." *Kans. Agr. Expt. Sta. Cir. 80.* 1920.

[b] Waters, H. J. "Studies of the Timothy Plant." Part I. *Mo. Agr. Expt. Sta. Res. Bul. 19*, p. 12. 1915.

[c] Swanson, C. O. "The Feeding Constituents of Alfalfa." *Kans. State Bd. Agr. (Quart.) Rpt.* Vol. 35, No. 138, p. 405. June, 1916.

The palatability of the crop at various stages is also an important consideration in determining the stage to cut.

Waters,[4] at the Missouri Station, studied the palatability of tim-

666b. Composition of grasses and clover at different stages of growth. Illinois.

	Water %	Water-Free Substance %					Nitrogen %	
		Crude Ash	Crude Fat	Crude Protein	Crude Fiber	Nitrogen Free Extract	Total	Albuminoid
Timothy								
Full bloom	26.53	6.81	5.00	7.33	32.11	48.75	1.17	0.96
Half the anthers shed ..	20.75	6.65	4.46	6.56	33.74	48.59	1.05	1.02
Seed in dough	23.41	6.73	3.81	6.12	34.45	48.89	0.98	0.95
Seeds in half to two-thirds of heads ripe ..	21.64	5.90	3.38	6.23	33.82	50.67	1.00	0.91
Kentucky Bluegrass								
Panicle just visible	6.65	8.07	4.88	19.88	18.43	48.74	3.18	2.70
Panicles spreading	7.15	5.57	4.07	16.21	22.83	51.32	2.68	2.38
Full bloom	6.98	8.30	3.90	12.61	23.76	51.43	2.01	1.99
In seed	7.55	6.38	4.25	12.49	24.34	52.54	2.00	1.63
Medium Red Clover								
Heads forming	11.00	8.42	4.52	23.31	17.53	46.22	3.73	...
Heads formed	9.73	7.73	3.58	18.36	23.37	46.96	2.94	...
Full bloom	9.82	7.07	3.16	14.66	28.06	47.05	2.35	...
Some heads dead	9.05	6.60	3.08	13.69	36.40	40.23	2.19	...
Heads all dead	10.13	6.19	2.78	12.52	37.50	41.01	2.00	...
Mammoth Red Clover								
First cutting, June 30 ..	26.31	7.89	6.65	13.84	30.32	41.30	2.21	1.87
Second cutting, July 11 .	25.79	6.57	5.82	12.83	34.75	40.03	2.05	1.82
Third cutting, July 23 ..	19.53	6.44	5.11	11.37	32.92	44.16	1.82	1.75

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[4] Waters, H. J.—"Studies of the Timothy Plant." Part I. *Mo. Agr. Expt. Sta. Res. Bul. 19*, p. 34. 1915.

othy hay cut when just coming into bloom, in full bloom, seed just formed, seed in the dough stage, and when the seed were ripe. Milk cows, fed the timothy with grain and silage, showed a preference for the early cutting. Steers fed on timothy hay alone seemed to show a slight preference for the earlier cutting. Sheep showed no preference between the different cuttings.

Sometimes the stage of maturity at which the crop must be harvested is determined by the changes which occur in the plant as it approaches maturity. For example, crimson clover for hay production is usually harvested before the beards of the seed head have hardened. Sweet clover must be harvested before it becomes woody. Mature barley awns are not desirable in hay. The stage of cutting also is influenced by the danger of mechanical loss due either to lodging or to the shattering of leaves, particularly in the case of legumes. When maturity approaches, particularly in the case of the annual legumes, the plants start shedding their leaves and by full maturity when the seeds are ripe very few leaves will be found on the stalks. These leaves carry a very high per cent of the nitrogen and the quality of the hay is reduced if they are lost.

In general, for both grasses and legumes, delaying the time of harvesting until the seed are mature decreases the palatability and the digestibility of the hay.

Another factor influencing the time of cutting biennial and perennial forage crops is the effect which cutting at a particular stage has on the continued productivity of the field. Graber *et al.*,[5] at the Wisconsin Station, found that frequent cutting of alfalfa or cutting at an immature stage soon depleted the organic root reserves with the result that the vigor and productivity of the plants was greatly reduced. The mortality, both winter and summer, of the alfalfa plants was accentuated by the frequent, early removal of the top growths. They also secured similar results in the case of timothy, blue grass, and redtop.

667. Composition of Grass and Legume Hays. The choice of a crop for hay will depend upon many factors, of which the composition, particularly the protein content, is one. The composition varies considerably depending upon the stage of maturity when the crop is cut.

Piper *et al.*[6] report the composition and digestible nutrients in various grass and legume hays together with an average for grasses and for legumes in Table *667a*.

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[5] Graber, L. F., Nelson, N. T., Luekel, W. A., and Alberts, W. B.—"Organic Food Reserves in Relation to the Growth of Alfalfa and Other Perennial Herbaceous Plants." *Wis. Agr. Expt. Sta. Res. Bul. 80.* 1927.

[6] Piper, C. V., *et al.*—"Hay." *U. S. Dept. Agr. Yearbook 1924*, p. 326.

667a. Grass and legume hays, their composition and digestible nutrients.

HAY	WATER %	ASH %	CRUDE PROTEIN %	CARBOHYDRATES		FAT %	DIGESTIBLE NUTRIENTS	
				Crude Fiber %	Nitrogen-Free Extract %		Protein %	Carbohydrate Equivalent %
Grasses								
Barley	10.6	5.3	9.3	23.6	48.7	2.5	6.0	47.6
Italian rye	8.5	6.9	7.5	30.5	44.9	1.7	3.3	47.5
Johnson	9.0	7.0	8.2	29.7	43.4	2.7	3.6	47.1
Millet	10.3	7.9	8.8	27.0	43.3	2.7	5.1	48.3
Tall oat	11.0	6.8	7.9	29.6	41.9	2.8	4.2	41.7
Orchard	9.9	6.0	8.1	32.4	41.0	2.6	4.9	45.5
Black grama	5.5	7.0	4.3	31.4	50.5	1.3	1.2	38.2
Mixed prairie	9.5	7.7	6.1	30.5	44.0	2.2	2.3	42.6
Western wheat	6.4	7.3	7.4	33.7	42.8	2.4	4.0	52.2
Redtop	8.9	5.2	7.9	28.6	47.5	1.9	4.8	49.1
Rye	6.4	4.7	5.9	37.4	43.6	2.0	3.1	45.4
Sorgo	5.8	9.5	9.5	26.8	46.5	1.9	3.5	48.0
Sudan	5.3	8.1	9.7	27.9	47.3	1.7	4.8	44.2
Swamp	11.6	6.7	7.2	26.6	45.9	2.0	3.0	43.4
Timothy	12.5	5.4	6.8	28.3	44.3	2.7	3.3	44.7
Average	8.8	6.8	7.6	29.6	45.0	2.2	3.8	45.7
Legumes								
Alfalfa	8.3	8.9	16.0	27.1	37.1	2.6	11.5	42.0
Alsike clover	10.5	8.8	14.4	24.7	39.1	2.5	9.5	40.3
Cowpea	9.7	12.9	17.5	20.5	36.6	2.8	11.9	37.0
Crimson clover	9.6	8.6	15.2	27.2	36.6	2.8	10.5	37.7
Field pea	10.6	8.3	16.1	24.8	37.5	2.7	12.6	45.3
Lespedeza	7.9	6.2	11.9	28.5	42.7	2.8	7.9	44.8
Mammoth red clover	12.2	7.5	12.8	27.1	37.1	3.3	7.8	43.2
Peanut	7.6	6.9	11.4	23.4	43.3	7.4	7.9	57.8
Red clover	12.9	6.9	13.6	24.1	39.1	3.4	8.3	43.2
Sweet clover	8.1	7.5	16.2	25.9	39.5	2.8	12.1	39.2
Soybean	8.4	8.9	15.8	24.3	38.8	3.8	11.2	44.0
Vetch	11.3	7.9	17.0	25.4	36.1	2.3	11.6	43.4
Average	9.7	8.3	14.8	25.2	38.6	3.4	10.2	43.2

668. Crops Harvested for Hay in Different Parts of the Country. The proportionate acreage of the various crops which are grown for hay in the different sections of the country varies greatly. For example, it will be observed from Table *668a* that in the corn belt 4.5 per cent of the hay acreage is alfalfa, while in the western part of the United States it is exactly 10 times this; in the cotton belt 23 per cent of the hay acreage is planted to annual legumes, while in other sections of the country they constitute less than one per cent.

669. Miscellaneous Tame Grasses Cut for Hay. Timothy constitutes by far the greater part of the total of tame grasses cut for hay. Piper *et al.*[7] have estimated the probable acreage and production of other annual and perennial grasses included in the census under the one item "Other tame or cultivated grasses cut for hay," as shown in Table *669a.*

668a. Relative importance of different crops harvested for hay in the different sections of the country, expressed in per cent.[8]

SECTION OF THE COUNTRY	TIMOTHY AND CLOVER	TIMOTHY	CLOVER	ALFALFA	ANNUAL LEGUMES	GRAIN HAY	WILD HAY	OTHER TAME GRASSES
Corn belt	47.5	23.7	6.5	4.5	0.8	2.2	8.7	6.1
Cotton belt ...	9.1	2.9	12.2	6.0	23.7	10.0	7.7	28.4
Western part of the U. S..	3.9	2.6	1.0	45.0	0.7	10.8	30.2	5.8

669a. Miscellaneous tame grasses cut for hay: Estimated acreage, production, and aggregate feed value in 1919.

KIND OF GRASS	ESTIMATED ACREAGE	ESTIMATED PRODUCTION	THEORETICAL ANNUAL RATION	ANIMAL UNITS EACH ITEM WOULD THEORETICALLY SUPPORT FOR ONE YEAR
	Thousands	Thousands of Tons	Tons	Thousands
Redtop	1,000	800	8	100
Orchard grass	800	800	8	100
Millets	750	1,000	8	125
Kentucky bluegrass	650	400	8	50
Sudan grass	600	1,050	8	131
Crab grass	600	500	8	63
Bermuda grass	400	400	8	50
Johnson grass	400	500	8	62
Miscellaneous	856	954	8	119
Total	6,056	6,404	..	800

670. Cereal Hay. Oats, barley, and rye are commonly used for hay in various sections of the country. In California the yields of hay[9] from Coast barley, white Australian wheat, Coastblack oats, and rye were found to be 4.5, 7.0, 6.6, and 6.8 tons per acre, respectively, in a favorable year. In a year of drouth the yields were 4.8, 4.2, 3.7, and 3.8 tons, respectively. The yields of hay of these four cereals cut at four different stages are given in Table *670a.*

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[7] Piper, C. V., *et al.*—"Our Forage Resources." *U. S. Dept. Agr. Yearbook 1923*, p. 357.

[8] Piper, C. V. *et al.*—"Hay." *U. S. Dept. Agr. Yearbook 1924*, p. 308.

[9] Hendry, Geo. W.—"Cereal Hay Production in California." *Calif. Agr. Expt. Sta. Bul. 394.* 1925.

Hendry states that the current opinion among California stockmen is that cereal hay of all varieties should be cut in the milk if intended for dairy cows and in the dough if intended for stock cattle or horses, but that oat hay for driving or riding horses should be cut in the milk and barley hay for work horses should contain considerable ripened grain. Rye must be cut in the blossom stage or earlier to yield hay comparable to the others in texture and palatability.

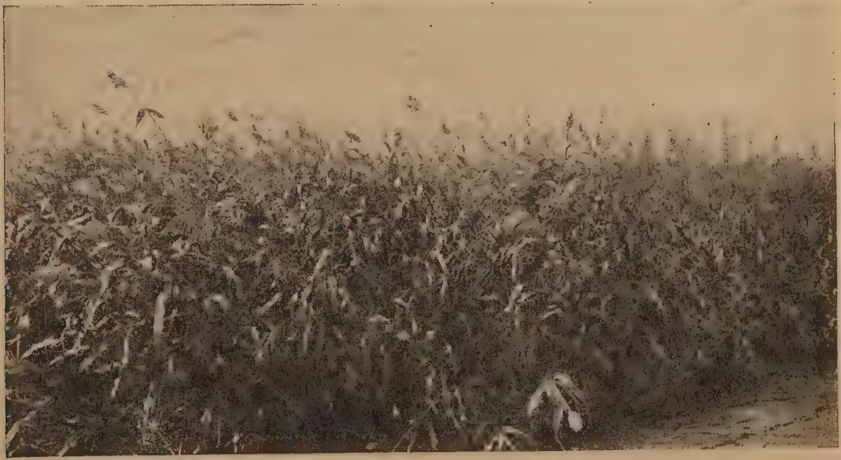

FIG. 120.—Sweet sorghum seeded broadcast at the rate of 40 pounds per acre. *Where a seeding of clover, alfalfa, or grass has failed what is the best annual emergency crop which can be seeded? Consider adaptation to local conditions, both soil and climate, cost of seeding, yield, palatability, and nutritive value.*

Hendry also reports that wheat hay harvested in the blossom, milk, dough, and ripe stages and offered to dairy cows was consumed in the order of maturity, the blossom hay first and the ripe hay last.

670a. Yields of cereal hay at successive stages of maturity.

STAGE CUT	AVERAGE YIELDS IN TONS PER ACRE			
	Barley	Wheat	Oats	Rye
Blossom	5.40	6.32	5.95	5.20
Milk	5.70	7.65	8.22	7.77
Soft dough	5.57	8.20	8.32	7.27
Ripe	4.40	7.42	7.35	7.22

Analysis of cereal hay cut at various stages showed that the percentage of ash and of proteins showed a tendency to decline as maturity was approached. Crude fiber was highest in rye and lowest in barley and increased in all cereals from the soft dough to the ripe stage. The percentage of carbohydrates showed an increase in all cereals from the blossom to the milk stages except in the case of oats and a decrease between soft dough and ripe in all cereals except barley.

PASTURES

671. Acreage and Productivity of Pasture. (See also Chapter XXVI.) Piper, *et al.*[10] state that 55 per cent of the total land area of the United States is used for grazing. This is over 4 times the area of the crops harvested for feed, yet the total sustenance derived from pastures is somewhat less than that produced by the harvested crops. Over half of the grazed land is arid grassland and desert shrub land, too dry for crop production; ⅕ is forest and cutover land; and more than 1/10 hilly upland in humid regions, too rough and stony for the production of crops. Only a little over 1/10 of the grazed area is improved land or land in rotation pasture or permanent pasture, which could be used for the growing of harvested crops.

The carrying capacity of our pastures in comparison to that of pasture in European countries is relatively lower than the yields of our harvested crops. The acres in humid pasture per animal unit in the United States and in other[11] countries are about as follows: United States, 3.80; Great Britain and Ireland, 2.65; France, 2.06; Netherlands, 1.60; Denmark, 1.46; Germany, 1.24; and Belgium, 0.91. Piper *et al.*[12] state that these differences reflect largely variations in the degree of dependence on pastures rather than differences in carrying capacity of pastures, while Gray *et al.*[13] report, as a result of a study of about 10,000 questionnaires considering the carrying capacity of the humid grassland pastures in the United States, that the average carrying capacity for the usual grazing season (averaging about six months) is 2.3 acres per animal unit or about 0.45 animal units per acre. This includes wood, brush, and rocky mountainous land.

672. Relative Importance of Pasture Plants. Piper *et al.*[14] gives the relative importance of the different plants used in permanent pastures in this country as follows: Kentucky bluegrass makes up 34 per cent; white clover, 14; redtop, 7; Bermuda, 5; timothy, 4; Canada bluegrass, 4; orchard, 4; and all other miscellaneous grasses, 28 per cent.

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[10] Piper, C. V., *et al.*—"Our Forage Resources." *U. S. Dept. Agr. Yearbook 1923*, p. 365.

[11] Gray, L. C., *et al.*—"Utilization of Our Lands for Crops, Pasture, and Forests." *U. S. Dept. Agr. Yearbook 1923*, p. 470.

[12] Piper, C. V., *et al.*—"Our Forage Resources." *U. S. Dept. Agr. Yearbook 1923*, p. 365.

[13] Gray, L. C., *et al.*—"Utilization of Our Lands for Crops, Pasture, and Forests." *U. S. Dept. Agr. Yearbook 1923*, p. 472.

[14] Piper, C. V., *et al.*—"Our Forage Resources." *U. S. Dept. Agr. Yearbook 1923*, p. 375.

673. Relative Carrying Capacity of Pasture and Hay Land. Two and one-half acres of tame pasture in the northeastern United States will provide sustenance for one mature animal for 6 months.[15] The quantity of grass hay necessary to support one animal unit for 12 months is estimated at 8 tons and of legume hay, 5 tons. He states that timothy meadows would have to yield approximately one and six-tenths tons of hay per acre and legumes 1 ton per acre to be equivalent to the carrying capacity of good tame pastures; 7.35 acres of timothy or native grass hay and only 3.01 acres of alfalfa or clover are necessary to support an animal unit for one year, while it requires 8.67 acres of pasture to support an animal unit for the same length of time.

674. Carrying Capacity of Pastures in Different Sections. The carrying capacity of different pastures in a given area will vary greatly. Topography, soil, rainfall, and temperature are all factors which have a part in determining the average capacity of pastures in a particular region. In the corn belt and in the southwestern portion of the hay and dairying regions, where the soil is naturally rich and rainfall ample, most of the pastures will carry an animal unit on 1 to 2 acres. The lowest carrying capacity—over 75 acres per animal unit—is in the arid interior plateau region and in the dense forests of the North Pacific coast. The areas having the greatest percentage of tame pastures generally have the highest carrying capacity.

675. Length of the Grazing Season. The length of the grazing season ranges from less than 5 months in the extreme northern part of the United States to the year round in parts of the most southern states. The average length of the grazing season is about 6½ months.

676. Annual Crops Pastured Off When Mature. An increasing acreage of annual crops is being harvested as pasture. In the more

676a. Mature crops pastured off: Acreage, production, quantity eaten by livestock, and aggregate feed value in 1919.

CROP PLANT	THOUSANDS OF ACRES	PRODUCTION—THOUSANDS OF TONS	ESTIMATED QUANTITY EATEN BY LIVESTOCK—THOUSANDS OF TONS	THEORETICAL ANNUAL RATION—TONS	THOUSANDS OF ANIMAL UNITS EACH ITEM WOULD THEORETICALLY SUPPORT FOR ONE YEAR
Corn	2,350	3,525	2,468	7	353
Cowpeas ..	1,000	800	800	5	160
Velvet beans	800	800	800	5	160
Peanuts ...	1,125	750	750	5	150
Soybeans ..	174	160	160	5	32
Total ...	3,107	6,035	4,978	..	855

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[15] Piper, C. V., *et al.*—"Hay." *U. S. Dept. Agr. Yearbook 1924*, p. 305.

northern states corn and soybeans are the two crops so harvested, while in the South cowpeas, velvet beans, and peanuts are most important, as shown in Table *676a*.

STUDY QUESTIONS ON CHAPTER XXIV

1. How does the acreage of forage crops rank with that of grain? With fiber and special crops?
2. What two great groups of plants furnish most of our forage?
3. What qualities make a crop a good forage crop?
4. How does the palatibility of a crop change with approaching maturity? How does its protein content and carbohydrate content vary with maturity?
5. List the forages high in protein. In carbohydrates.
6. Make a list of the important hay crops, arranging them according to acreage. According to the yield per acre. According to the feeding value per unit.
7. You operate a general stock farm. Can you get the greatest net value from your oat crop by binding and threshing or by cutting for hay? Explain.
8. Why are soiling crops not more generally used?
9. What are the essentials of a good pasture?
10. Describe pasture conditions in your section. What is the trend in the relative acreage of the different kinds of pasture?
11. How can the value of pasture returns be measured?
12. What trend do you predict in the future in the use of permanent pasture as compared with temporary or short rotation pastures? Explain.

APPLICATION ASSIGNMENTS ON CHAPTER XXIV

1. Your 160-acre farm has 55 acres in pasture. How does this influence you in determining what you will grow on the remainder of the farm?
2. Thirty acres of the above 55 acres of pasture are on average tillable farm land. Two and one-half acres of this is required to provide the pasturage for one cow. Similar land in cultivation rents for $8.00 per acre. You can rent pasture for $5.00 per acre. Will you plow this 30 acres and crop it? Why?
3. You have pastured your land heavily all season. The grass appears to be short but the cattle are doing well. You can rent additional pasture at a reasonable rate. What will you do? Why?
4. On a farm with only 20 acres of permanent pasture you plan to maintain 50 head of cattle annually. In what ways may you handle this situation? Explain.
5. You have 50 head of cattle and must grow hay for them. What considerations determine the crops which you will grow? You want a hay crop high in protein. What crop will you grow?

6. Your hay crop is to be put in on corn stubble land. How will you prepare the land and seed the crop?
7. Your timothy, in a timothy and clover mixture, is barely starting to bloom. You can cut now, or it will be necessary to delay the cutting for two weeks. What will you do? Why?
8. Suppose the above crop were alfalfa at a similar stage; what would you do? Why?
9. In a good oat year your oats have made an excellent growth and you estimate that the yield of grain will be 50 bushels per acre. Your hay acreage is low. You are thinking of cutting the oats for hay. Will you do it? Why?

CHAPTER XXV

HAY AND HAY MAKING

Hay is almost always cut with a mowing machine, although the self-rake reaper is occasionally used and in certain cases the grain binder. Recently, several investigators have tested methods of curing hay. The primary object of curing hay is to reduce the moisture so that the hay may be stored with safety, but in the curing process other changes also occur.

677. Moisture Content of Hay Plants. The moisture content of the plant at the time of cutting depends very largely on the stage of maturity and the environmental conditions. The average moisture content of the growing crop in the field, as well as the range in moisture content of representative crop plants is given by Vinall and McKee.[1]

677a. Moisture content of representative crops at harvest.

CROP	GREEN MATERIAL, PER CENTS			
	Number of Analyses	Average	Maximum	Minimum
Alfalfa	23	71.75	82.03	49.30
Red clover	43	70.79	91.78	47.13
Timothy	56	61.58	78.70	46.98
Kentucky bluegrass	18	65.07	82.53	51.67
Corn	126	79.33	93.60	51.50
Sorghum	11	79.40	86.38	63.88

The above also report the moisture content of representative crops when harvested at different stages of maturity. The moisture content of timothy was determined when the plant was in the following stages; heads not visible, heads just appearing, heads fully out, beginning to bloom, full bloom, past bloom, nearly ripe, seed fully formed, seed becoming hard. The percentage of moisture at these different stages was 74.4, 72.94, 70.8, 66.7, 64.27, 59.82, 59.28, 54.25, and 49.15, respectively. In alfalfa when the plant was 18 inches high the moisture content was 83.32 per cent, when in bud the moisture content was 79.05 per cent, and when fully ripe, the moisture content was 55.92 per cent. In red clover, when the heads were not visible, the percentage of moisture was 82.55, and there was a gradual decrease down to 61.05 when the plant was classed as nearly ripe. The first cutting in bloom had 81.78 per cent moisture; the second cutting in young bloom 77.52, and the third cutting in young bloom 72.51 per cent moisture.

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[1] Vinall, H. N., and McKee, Roland—"Moisture Content and Shrinkage of Forage." *Jour. Amer. Soc. Agron.* Vol. 8, No. 2, p. 92. Mar.-Apr., 1916.

Henson [2] determined the moisture content of alfalfa growing in the field each hour, from eight in the morning until eight in the evening, as shown in Table *677b*.

677b. Moisture content of alfalfa as determined at hourly intervals (1) on July 19 and (2) Aug. 5, 1928, Iowa.

	8 A.M.	9	10	11	12	1	2	3	4	5	6	7	8 P.M.
(1)	78.2	77.7	77.0	75.9	76.3	77.0	76.9	76.0	76.4	76.5	76.2	75.8	77.0
(2)	74.3	73.5	72.6	71.8	72.2	73.5	72.6	72.9	72.5	72.7	72.6	72.8	73.6

When the July determinations were made, the alfalfa was just beginning to bloom, while in August the crop was in full bloom.

678. Moisture Content of Field-Cured Hay. The moisture content of the field-cured hay varies widely. In alfalfa, the reported

678a. Moisture content of hay when field-cured and ready for storage and of well-cured barn or stack hay.[3]

CROP	FIELD-CURED HAY MAXIMUM PER CENT	WELL-CURED BARN OR STACK HAY PER CENT		
		Minimum	Average	Difference Between Minimum and Maximum Water Content
Timothy (all analyses)	28.9	6.1	11.6	22.8
Timothy, early to full bloom	28.9	7.0	12.8	21.9
Timothy, late bloom to early seed	21.6	7.0	14.1	14.6
Redtop (all analyses)	28.0	6.8	9.8	22.2
Redtop, in bloom	...	6.8	8.0	...
Alsike clover	...	5.3	12.3	...
Alfalfa (all analyses)	30.0	4.6	8.6	25.4
Red clover (all analyses)	31.3	6.0	13.0	25.3
Cowpea	...	7.6	9.7	...
Soybean	20.0	6.1	8.6	13.9
Johnson grass	...	...	10.1	...
Barley	15.0	6.4	10.0	8.6
Oats	26.5	9.5	12.0	17.0
Rye	...	...	8.1	...
Wheat	...	...	8.1	...
Prairie	17.1	6.5	10.0	10.6

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[2] Henson, E. R.—Unpublished Data. *Ia. Agr. Expt. Sta. 1928.*

[3] From *U. S. Dept. Agr. Farmers' Bul.* 22, 1901; Henry's *Feeds and Feeding.* Sixteenth Edition, and various experiment station reports.

variations are from a minimum of 4.6 per cent to a maximum of 33 per cent. Legume hay ordinarily is considered cured when the moisture content has been reduced to between 15 and 20 per cent. Vinall and McKee,[4] working in Kansas, Pennsylvania, and Rhode Island, found the average per cent of moisture in various types of hay at the time they were placed in storage to be 22.63. The range in moisture content was from 6.20 to 36.16 per cent.

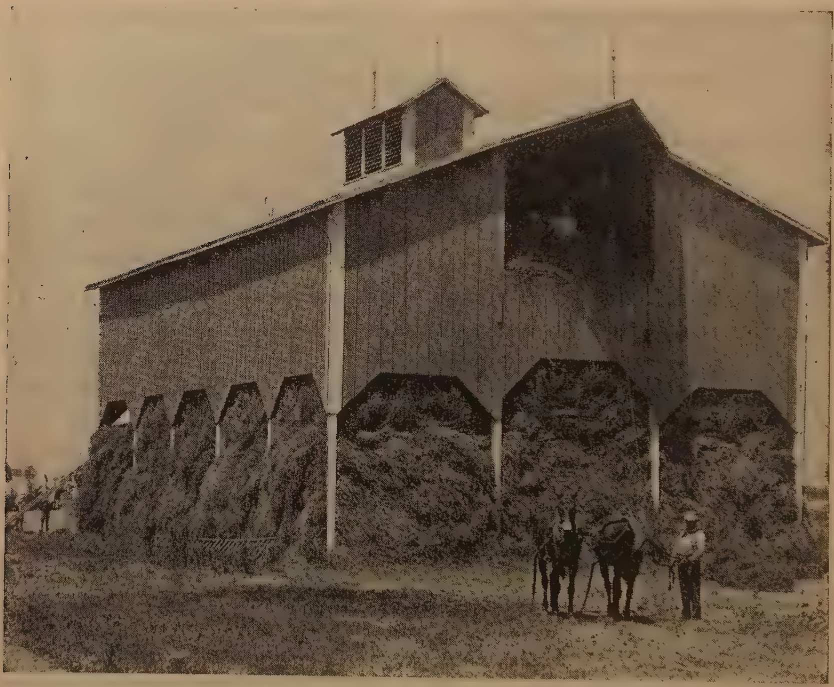

FIG. 121.—Putting alfalfa hay in a hay barn. *How high a percentage of moisture can hay carry and be safe to put in the mow? What is the relation between the per cent of moisture when mowed and the quality of hay produced? How much shrinkage is likely to occur in the barn?*

McClure has compiled [5] the results of various experiments showing the maximum per cent of moisture in field-cured hay when stored, also the minimum and average per cent for well cured barn or stack hay.

679. Fluctuations in Moisture Content of Cured Hay. Oregon [6] states that baled hay gained 100 to 150 pounds per ton during the winter, through March, then gradually lost weight during the drier months until the weight was practically the same as when first baled.

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[4] Vinall, H. N., and McKee, Roland—"Moisture Content and Shrinkage of Forage." *Jour. Amer. Soc. Agron.* Vol. 8, No. 2, pp. 94-95. Mar.-Apr., 1916.

[5] McClure, H. B.—"The Shrinkage of Market Hay." *U. S. Dept. Agr. Dept. Bul. 873.* 1920.

[6] Jardine, J. T.—"Director's Biennial Report." *Ore. Agr. Expt. Sta. Biennial Rpt. 1920-22,* p. 46.

The moisture content of the hay varies somewhat during the day. Vinall and McKee found[7] that the moisture content at 8 o'clock in the morning was one per cent greater than it was at 3 o'clock in the afternoon.

680. Shrinkage of Hay in Mow and Stack—Summary. McClure[8] summarizes information and experiments on shrinkage as follows:

"The percentage of shrinkage in hay is influenced by the following factors: (1) water content when cut, (2) maximum water content when stored, (3) normal water content when cut, (4) minimum water content, (5) atmospheric humidity, and (6) effect of time.

"Many experiments have been conducted, during the last 30 years, to determine the rate of shrinkage in hay in the barn and stack. The loss in weight was found to range from 0.29 per cent to 42.2 per cent and the gain in weight ranged from 0.4 per cent to 10.7 per cent, making a total variation of nearly 53 per cent.

"The widespread publication of experimental data showing comparatively large losses by shrinkage, during several months, has been misleading, especially to producers, because the investigators failed to point out *that the greater part of the loss occurs before the hay is in proper condition to be baled or marketed* and that the loss, which is practically of water only . . ., should have no commercial value."

681. Rapidity with Which Moisture Is Lost in Field Curing. Vinall and McKee[9] weighed samples of alfalfa, oat grass, timothy, and sorghum as soon as harvested and again after ½, 1, 2, 3, and 4 hours. The samples were handled in canvas to prevent the loss of leaves and in some cases spread out in the swath and in others piled to simulate windrow curing.

The average loss in moisture between weighing intervals is shown in Table *681a*.

Henson[10] tested the rate of loss of moisture from alfalfa under field conditions. Ten-foot sections of windrow and of swath were weighed immediately after cutting and at various intervals thereafter. The hay was lifted by means of special equipment, and weighed, then

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[7] Vinall, H. N., and McKee, Roland—"Moisture Content and Shrinkage of Forage and the Relation of These Factors to the Accuracy of Experimental Data." *U. S. Dept. Agr. Dept. Bul. 353.* 1916.

[8] McClure, H. B.—"The Shrinkage of Market Hay." *U. S. Dept. Agr. Dept. Bul. 873.* 1920.

[9] Vinall, H. N., and McKee, Roland—"Moisture Content and Shrinkage of Forage and the Relation of These Factors to the Accuracy of Experimental Data." *U. S. Dept. Agr. Dept. Bul. 353.* 1916.

[10] Henson, E. R.—Unpublished Data. *Iowa Agr. Expt. Sta. 1927.*

681a. Rapidity with which moisture is lost in curing.

Crop and Location	Moisture Loss, per Cent				
	½ Hr.	1 Hr.	2 Hrs.	3 Hrs.	4 Hrs.
Alfalfa at Chico, Calif.	..	17	35	..	69
Alfalfa at Arlington Farm, Va.	6	14	23	28	32
Tall oat grass and orchard grass at Arlington Farm, Va.	5	12	24	30	34
Timothy at New London, Ohio	6	10	18	25	30
Sorghum at Hays, Kans.	2	5	9	12	13

lowered back into place without disturbing the position of the plants or loss of leaves.

Date	Method of Curing	Moisture Content at the End of the Time Given				
		2 Hrs.	4 Hrs.	6 Hrs.	8 Hrs.	24 Hrs.
July 7	Swath curing	...	49.3	39.7	...	26.4
July 7	Windrowed at once	...	51.0	43.7	...	28.4
July 8	Swath curing	52.6	...	35.13	32.8	21.2
July 8	Windrowed at once	59.0	...	43.9	37.5	25.0
Aug. 22	Swath curing	49.4	...	39.7	34.5	...
Aug. 22	Windrowed at once	50.7	...	43.6	35.8	...

682. Methods of Field Curing Compared. Various methods and systems of curing hay have been used, but perhaps the most widely advertised method is the so-called "Dain System." In this system a left-hand, side-delivery rake with curved teeth, driven in the same direction as the mower soon after cutting the hay, rakes two swaths into a windrow. It is claimed that by raking in this way and at this time the leaves are thrown to the center of the windrow, where they keep their color better and keep alive longer than if the hay is left exposed in the swath, while at the same time the stems are on the outside of the windrow. When the hay is partially cured, the windrow is turned with the tail end of the rake; that is, it is turned half over, exposing the bottom side of the windrow. Another advantage claimed is that this system of hay making removes the hay from the damp ground and places it on clean, somewhat drier stubble, hastening the curing process. This system may be modified, allowing the hay to become partially cured in the swath, perhaps one-fourth to one-half cured, before placing in the windrow. When the ordinary dump rake is used, the hay is usually allowed to become more nearly dry in the swath before it is placed in the windrow.

In Nebraska, Kiesselbach and Anderson,[11] using 1/40 acre plots, compared nine different systems of curing alfalfa in the field. Hay with 30 per cent of moisture was considered field cured.

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[11] Kiesselbach, T. A., and Anderson, Arthur—"Curing Alfalfa Hay." *Jour. Amer. Soc. Agron.* Vol. 19, No. 2, pp. 118-126. Feb., 1927.

682a. Hours required to field-cure hay when different methods are used, also the per cent of total dry matter recovered. Nebraska.

METHOD OF CURING	30% MOISTURE CONTENT REACHED IN HOURS	HAY (DRY MATTER) RECOVERED WHEN		
		Field-Cured	Test Ended	All Plats Averaged
Swath, throughout	27	90.7	81.5	86.1
Windrow, throughout	56	99.9	95.3	97.6
Windrow, preceded by 3 hours swath curing	29	97.8	98.3	98.1
Windrow. preceded by 6 hours swath curing	27	99.1	94.4	96.8
Windrow, preceded by 24 to 27 hours swath curing	27	94.5	91.4	93.0
Average	35	97.8	94.9	96.4
Cock, throughout	104	96.3	96.3	96.3
Cock, preceded by 3 hours swath curing	32	98.4	98.0	98.2
Cock, preceded by 6 hours swath curing	30	96.3	96.5	96.4
Cock, preceded by 24 to 37 hours swath curing	29	95.0	91.5	93.3
Average	49	96.5	95.6	96.1

In a particular comparison swath-cured hay was reduced to 30 per cent moisture in 9 hours, while it required 28 hours for hay windrowed immediately with the side delivery rake to get down to 30 per cent. In a second test these two methods ranked practically the same.

The best quality of hay resulted from windrowing immediately though there was very little difference as compared with that partially swath-cured. The particular advantage of the partial swath-curing is that it materially hastens the curing. They also found that as soon as hay is field cured it should be removed and placed in storage, as losses in quality and from shattering are very great if the hay is permitted to remain in the field longer than is necessary for safe storage.

683. Time of Cutting. Parker states[12] that the best time of cutting alfalfa depends upon the local climatic conditions. In arid sections where dews are uncommon one of the best practices is to cut in the late afternoon and begin raking very early in following morning, while in regions of dews and cool nights one of the best methods is to begin cutting in the early morning, raking and windrowing within a few hours after cutting.

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[12] Parker, Edward C.—"High Grade Alfalfa Hay: Method of Producing, Bailing, and Loading for Market." *U. S. Dept. Agr. Farmers' Bull. 1539.* 1929.

Carrier[13] advocates mowing late in the afternoon or during cloudy weather, stating that under these conditions much of the moisture in the stem passes out through the leaves. Many others have expressed this same view.

684. Function of the Leaves in Curing Legume Hay. McClure[14] states that in growing plants there is a constant stream of water entering the roots, carrying plant food to the leaves, where the excess water is eliminated by transpiration. He expressed the opinion that when the plant is cut off, as in the case of hay, the leaves, if kept alive, will continue to transpire or pump the water from the plants until a considerable part of it has been evaporated.

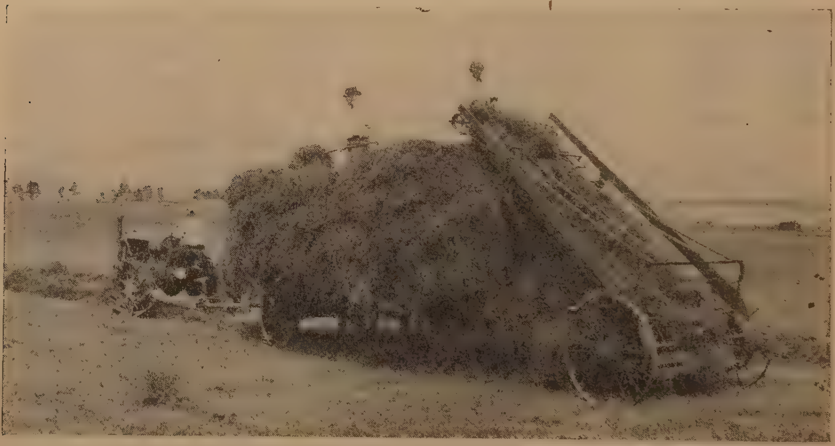

FIG. 122.—Loading alfalfa hay from the windrow. *Will this method of handling alfalfa hay result in an excessive loss of leaves? Explain.*

Westover[15] conducted an experiment in which he compared the rate of moisture loss in alfalfa cured with the leaves attached and with the leaves removed. The rate of loss of moisture in the stems themselves, without leaves, and with leaves, was practically the same. The leaves seemed to lose moisture just as rapidly where they were attached to the plant as where they were removed. The leaves lost moisture much faster than the stems, but apparently did not aid the stem in getting rid of its moisture.

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[13] Carrier, Lyman—"Hay." *The Book of Rural Life.* Vol. 4, p. 2527. Bellows-Durham Co. Chicago. 1925.

[14] McClure, H. B.—"Hay Making." *U. S. Dept. Agr. Farmers' Bul. 943.* 1918.

[15] Westover, H. L.—"Comparative Shrinkage in Weight of Alfalfa Cured with Leaves Attached and Removed." *U. S. Dept. Agr. Dept. Bul. 1424.* 1926.

Willard[16] cured out small samples of various crops with the leaves attached, in comparison with samples with the leaves cut off and placed alongside the plant about where they would have been if not severed from the plant. He concluded that the leaves have no tendency to dry the stems in alfalfa, but that they do seem to aid in drying the stems in soybeans.

Kiesselbach and Anderson[17] compared the rate of curing alfalfa with the leaves on and with the leaves cut off. Their tests indicated that transpiration from the leaves did not aid materially in the curing process.

685. Other Changes Which Take Place in the Curing of Hay. In addition to the loss of moisture, which occurs as hay is being cured, and the possible loss from leaching in case of rain, there are changes which take place in the composition of the plant as a result of enzyme action. Mild fermentation is considered desirable in that it imparts aroma to the hay. The degree of fermentation which takes place is dependent on the moisture content of the hay. Well cured hay, if placed in the stack or the mow, goes through a very mild fermentation process. Imperfectly cured hay or that which has a high moisture content when piled either in the cock, stack, or mow goes through a very vigorous fermentation stage, usually accompanied by a marked rise in temperature, the destruction of part of the dry matter and a lowering of the quality of hay.

Bond[18] states that to insure satisfactory results, making use of a limited fermentation in the stack, secure complete drying, and an improvement of the aroma, the hay must be stacked before the plant cells are quite dead, when 5 to 10 per cent of excess moisture, not due to that of rain or dew, is still present. He states further that an excess of moisture often causes the hay to become bitter or moldy as a result of a cool sweat.

In connection with the fermentation it has been commonly claimed in the past that there was a loss of dry matter. McClure[19] states that the natural curing and the results of shrinkage in the barn do not involve destruction of dry matter because hay does not ordinarily contain enough water to engender temperatures high enough to injure the dry matter. McClure states that Keable and Wale working in England found that newly ricked clover hay, undergoing a natural fermentation, reached its maximum temperature toward the end of the first or the beginning of the second week and that a second fermentation occurred beginning about three weeks after the hay was ricked. There was a direct relation between the temperature and the water content of the hay when ricked, the highest temperatures occurring in the stacks which contained the largest percentage of water.

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[16] Willard, C. J.—"Do Legume Leaves Hasten the Curing Process by Pumping Moisture from the Stems?" *Jour. Amer. Soc. Agron.* Vol. 18, No. 5, pp. 369-375. May, 1926.

[17] Kiesselbach, T. A., and Anderson, Arthur—"Curing Alfalfa Hay." *Jour. Amer. Soc. Agron.* Vol. 19, No. 2, pp. 122-126. Feb., 1927.

[18] Bond, J. R.—"Haymaking." *Jour. Min. Agr.* [*London*] Vol. 31, No. 3, p. 223. 1924.

[19] McClure, H. B.—"The Shrinkage of Market Hay." *U. S. Dept. Agr. Dept. Bul. 873.* 1920.

In certain cases the temperature of hay may go to such extreme heights as to result in browning, or charring, or even in spontaneous combustion—burning (86).

686. Brown and Black Hay. In the production of brown hay the material contains considerably more moisture when it goes into the mow or stack than is usual, and considerably higher temperatures are noted. The high temperature steams out the moisture and kills molds and other organisms. It is important that the material be thoroughly well packed and in sufficient quantity to exclude the easy access of fresh, cool air. Brown hay is very palatable though in some cases it may be slightly lower in feeding value than green hay. By placing hay in the mow before the ordinary state of dryness has been reached, danger of loss from unfavorable weather is reduced, though the danger of charring or spontaneous combustion is increased.

Swanson, Call and Salmon [20] report that partially wilted alfalfa, stacked without curing, undergoes changes which may result in the loss of as much as two-fifths of the organic matter. The loss apparently increases with the length of time it is in the stack and the degree of fermentative changes which occur. Alfalfa which has become black as a result of fermentation is very inferior as a feed for steers in comparison with brown alfalfa or with alfalfa hay of good grade and color.

687. Spontaneous Combustion in Hay. Lamb states [21] that the process begun by fermentation, in which bacteria and plant cell respiration both play a part, may raise the temperature to about 135° F. When the hay becomes as hot as this the rate of oxidation is greatly increased, heat thus produced raises the temperature still higher and the oxidation process proceeds even more rapidly. When the temperature approaches 200° F. the hay will begin to char. All hay which begins to char does not go on and burst into flame, probably because not enough oxygen reaches the hay.

McClure cites Hoffman [22] as having reported studies in 1897, when as much as one-half of the feed value of hay was lost as a result of these processes. He reports that clover hay may become ignited at from 302° F. to 392° F.

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[20] Swanson, C. O., Call, L. E., and Salmon, S. C.—"Losses of Organic Matter in Making Brown and Black Alfalfa." *Jour. Agr. Res.* Vol. 18, No. 6, p. 304. Dec. 15, 1919.

[21] Lamb, A. R.—"Spontaneous Combustion as a Cause of Fires." *Ia. Agr. Expt. Sta. Cir. 36.* 1917.

[22] McClure, H. B.—"The Shrinkage of Market Hay." *U. S. Dept. Agr. Dept. Bul. 873.* 1920.

688. Effect of Rain on Hay. Continuous rains apparently do but little more damage to the freshly cut plant than to the uncut plant, at least during the first few days after cutting, but cured or partially cured hay is seriously injured as a result of leaching.

Alfalfa hay exposed for 15 days to warm, humid weather at the Colorado Station,[23] during which time 1.76 inches of rain fell, showed a reduction in the protein content from 18.71 to 11.01 per cent.

Using the data of the Colorado Station, Willard [24] has shown that the exposure of alfalfa to rain caused a loss of 60 per cent of its protein, 33.3 per cent of its fat, 41 per cent of its nitrogen-free extract, and 28.7 per cent of its ash.

A similar test by Shuey [25] showed practically the same losses. In field curing, alfalfa lost 12 per cent of its dry matter, while when exposed to the rain it lost 22.8 per cent.

Sutherst [26] reports the following data with reference to the effect of wet weather on uncured hay. The chemical analysis of hay cured without exposure to rains is given in comparison with that exposed to two days of wet weather.

	PROTEIN	CARBO-HYDRATES	CRUDE FIBER	ASH
Protected hay	16.52	39.14	28.91	5.43
Exposed to weather	14.58	37.14	33.32	4.96

689. Kiln Drying Devices. Kiln drying devices are sometimes used in the making of hay. Perhaps the "Mason system" is best known. The green hay as cut is taken directly to the drier and there endless conveyors carry it through the drying chamber where a high temperature is maintained, quickly reducing the material to an air-dry condition. Alfalfa is usually ground into meal and sacked at once.

690. Stack Driers. Where the conditions for natural curing are very unfavorable a fan and heat has been used. This method of curing hay recently has been tried out rather fully in England.[27] Green hay is taken from the field soon after cutting and a layer of 3 or 4 feet placed on all sides and over a pyramid. Heated air is blown into the center of this pyramid by means of a combined heating unit and fan. By this method stacks of green hay have been brought down to a safe moisture content for storing in from 5 to 10 hours. In some cases the hay is allowed to heat naturally and air blown in without the use of artificial heat. This method has not been entirely successful.

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[23] Headden, William P.—"Alfalfa." *Colo. Agr. Expt. Sta. Bul. 35,* p. 12. 1896.

[24] Willard, J. T.—"The Composition and Digestibility of Alfalfa and Its Relation to Soil Fertility." *Kans. Agr. Expt. Sta. Bul. 155*, p. 289. 1908.

[25] Shuey, Ralph C.—"An Investigation of the Diastase of Alfalfa and the Effect of Rapid Curing upon the Food Value of Alfalfa." *Jour. Indus. Eng. and Chem.* Vol. 6, No. 11, p. 915. Nov., 1914.

[26] Sutherst, W. F.—*Chem. News*, Vol. 92, No. 2385, p. 61. 1905.

[27] "Preliminary Report of an Investigation into the Artificial Drying of Crops in the Stack." *Institute of Agr. Eng. Univ. of Oxford. Bul. No. 2.* Clarendon Press. Oxford. Eng.

Aitkenhead[28] describes a device made at the Indiana experiment station by which the air is drawn through a combustion chamber and the heated air and fumes blown into the center of the stack, similar to the method used in England. A 12-ton stack of soybeans was greatly over-dried by 11 hours of blowing, and an 8-ton stack well dried in 5 hours with the in-going air at 150° F. The stacks were then cooled by turning off the heat and blowing cold air for an hour. Due to the coarse straw the hot air transfused easily. A 10-ton alfalfa stack cut soon after a heavy shower was cured in 7½ hours, the temperature of the air being 160° F. Without the artificial drying this hay would undoubtedly have been lost. The cost for fuel was 63 cents per ton of green hay.

A portable device such as Aitkenhead has described should prove valuable on the farm in the event of a soft corn year in drying ear corn in the crib, following the method described by Hughes[29] in 1918. It should also prove useful in the drying and curing of seed corn and of grain.

691. Effect of Artificial Curing on the Feed Value. When hay is artificially dried, it does not go through the ordinary fermentation process. Artificially cured alfalfa hay has been compared in feeding value with green alfalfa and also that cured in the ordinary way. Piper *et al.*[30] report a comparison of the chemical composition of fresh green alfalfa, field-cured hay and artificially cured hay.

691a. Chemical composition, water-free basis.

	Ether Extract	Ash	Crude Fiber	Albuminoids	Nitrogen-Free Extract
Green alfalfa	2.89	9.09	27.65	19.16	40.92
Artificially dried	2.46	9.12	27.39	18.69	41.46
Field cured	2.12	6.87	28.14	13.71	49.26

In a few experiments conducted by the Department, farm animals distinctly preferred the artificially dried hay to the field cured, even when the hay was cured by hot gases carrying considerable smoke. Taking into account the quality of the artificially dried product and the saving of leaves of leguminous hay it probably is not an extravagant method. It is suggested that in humid sections the value of the artificially cured product might be 30 per cent greater than the ordinary field-cured product.

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[28] Aitkenhead, William—"Stack and Grain Drying." *Ind. Agr. Expt. Sta. Circ. 139.* 1928.

[29] Hughes, H. D.—"Drying Soft Corn." *Wallace's Farmer.* Vol. 43, No. 11, p. 486. Mar. 15, 1918.

[30] Piper, C. V., *et al.*—"Hay." *U. S. Dept. Agr. Yearbook 1924,* p. 336.

692. Use of Equipment in Handling Hay. A large part of the hay crop is loaded by hand and unloaded with a horse fork or with slings, though the use of hay loaders which pick the hay up either from the windrow or from the swath and place it on the wagon is becoming more general. McClure states that the objections to the use of the hay loader in many sections arise when the loaders have been used on rough or stony ground, and breakages in the machines have been frequent. Then, too, a man works very hard while the load is being put on and hired men object to having to do this. Another objection which has been made is that the slanted bottom of the hay loader permitted the loss of leaves, particularly from legume hay. This does not occur to any great extent when the hay has been properly handled in curing.

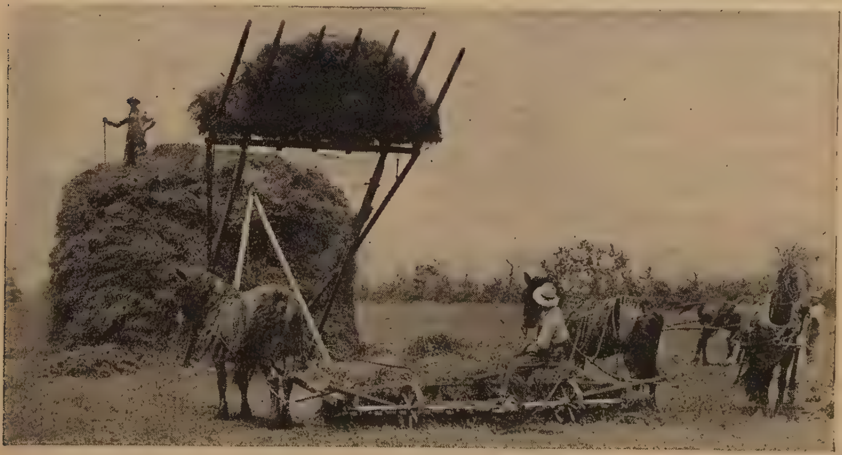

FIG. 123.—The most common method of stacking afalfa in the important alfalfa producing regions. *How does the cost per ton of making hay by this method compare with the cost of other methods?*

Another method of putting up hay is with a push rake or bull rake,—sometimes called "go devil," "slip around," etc., and a stacker. The bull rake takes the hay from the windrow without any hand labor being required and pushes the load to the stack. Push rakes are also used where baling in the field is a common practice. The stackers used are the overshot, the swing around, and the incline. The push rake and incline stacker make a good combination as practically all the work except that of placing the hay after it is on the stack is done with horse labor. In some sections where excessive rains occur or where the snowfall is heavy and hay is grown for the market, a part or all of the hay is put in sheds or barns. When stored in the hay shed, it is customary to use wagons for hauling the hay from the field, though in some cases the sheds are located in the field in which case push rakes or similar equipment may be used. In some parts of Nebraska hay barns are so located and constructed as to use an overshot stacker to put the hay directly into the barn. With this method sweep rakes are used to bring the hay in from the field and deliver to the stacker. Where hay is baled from the field the push rake brings the hay from the windrow to the baler. One of the latest devices for saving hand labor in handling hay is the combination baler which takes the hay directly from the windrow, bales it and delivers the baled hay to a wagon as the outfit travels through the field.

Over the larger part of the area where excess hay is produced the crop is stacked in the field and baled from the stack after it has gone through the sweat. The conditions under which hay can be baled in the field from the windrow are limited.

693. Curing Special Hays. In certain sections of the South, perches consisting of stakes 5 or 6 feet long with cross arms near the base are used in the curing of peanut and cowpea hay. The upright stake is driven into the ground and the hay draped around it, making a tall, slender cock. Various modifications of this are found in the pyramid or horse around which the hay is stacked, the horse or pyramid making an open space in the center of the cock which aids in the circulation of air and evaporation of moisture.

694. Hay Trucks. Special hay trucks, somewhat similar to the ordinary hay rack, are used for curing hay in certain sections of the South. They are possibly 12 feet long by 7 feet wide and hold from 1500 to 2000 pounds of cured hay. The trucks are left standing in the field where loaded, as hauling the hay any distance causes it to settle and retards curing. A standard at each end and a ridge pole supports a canvas cover, which protects the hay in rainy weather. Hay is placed on these trucks when about two-thirds to three-fourths cured, and allowed to complete its curing under the canvas cover of the truck.[31]

695. Labor Requirement in Hay Making. The haying operation, as carried out on many farms, is costly in labor. The labor required per acre and per ton varies greatly, depending upon the method and equipment employed. Piper *et al.*[32] have reported the average number of hours of man and horse labor used in making hay in representative states as shown in Table *695a.*

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[31] McClure, H. B.—"Curing Hay on Trucks." *U. S. Dept. Agr. Farmers' Bul. 956.* 1918.

695a. Average hours of labor used in harvesting hay crops in different states.[33]

KIND OF CROP AND STATE	QUANTITY CUT PER ACRE OF MEADOW	LABOR PER ACRE OF MEADOW (MOWING, RAKING, HAULING & STORING)		LABOR PER TON OF HAY CUT (MOWING, RAKING, HAULING & STORING)		PART OF ACREAGE CUT MORE THAN ONCE	
		Man	Horse	Man	Horse	Two Times	Three Times
	Tons	Hours				Per Cent	
Mixed[a]							
New York	1.4	7.9	7.7	5.6	5.5	...	...
Pennsylvania	1.5	7.5	7.8	5.0	5.2	...	...
Wisconsin	1.4	9.1	10.2	6.5	7.3	...	...
Minnesota	1.5	7.8	10.1	5.2	6.7	...	...
Timothy							
Wisconsin	1.4	9.1	11.0	6.5	7.9	...	...
Minnesota	1.3	8.0	11.4	6.2	8.8	...	...
Iowa	1.8	7.5	8.8	4.2	4.9	...	...
Clover							
New York	2.0	8.9	9.9	4.4	5.0	[b]	...
Wisconsin	2.2	14.2	15.5	6.5	7.0	33	...
Minnesota	1.5	8.6	12.4	5.7	8.3	50	...
Illinois	1.3	8.7	10.0	6.7	7.7	[b]	...
Alfalfa							
New York	2.2	14.4	16.0	6.5	7.3	91	64
Wisconsin	2.4	21.8	21.2	9.1	8.8	93	59
Minnesota	2.5	20.2	24.1	8.1	9.6	80	60
Illinois	1.9	19.2	23.7	10.1	12.5	[c]	[c]
Iowa	2.0	14.0	22.4	7.0	11.2	100	72
Colorado	3.3	17.1	24.3	5.2	7.4	100	[d]

[a] Mostly clover and timothy.
[b] Second crop used for seed or pasture.
[c] Not known.
[d] Exact percentage not known, but a very small percentage of the farmers varied from the usual practice of making 3 cuttings during the season.

Piper *et al.*[34] report a study of the number of hours of labor required on 235 corn belt farms in handling alfalfa by different methods with the results as shown on page 558.

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[32] Piper, C. V., *et al.*—"Hay." *U. S. Dept. Agr. Yearbook 1924*, p. 368.

[33] The data are not averages for states, but are the results from regional studies within the states. The data for Colorado apply to irrigated land. They were obtained at different times during the period 1902 to 1917.

[34] *Ibid.*, p. 375.

Operation	Hours per Acre	
	Man	Horse
1. Hay cut, raked, cocked, hauled and put into the barn by hand	8.6	7.6
2. Hay cut, raked, hauled from the windrow, put in the barn and pitched by hand	7.0	8.2
3. Hay cut, raked with a side delivery rake and put in the barn, hay loader used in loading	5.8	7.5
4. Hay cut, raked, hauled to the stack in the field with a buck rake, the hay stacked with a stacker	4.8	5.7
5. Hay cut and raked and hauled to the baler with a buck rake and to the barn on a wagon	9.5	9.9

The labor required per acre in the different haying operations when up-to-date machinery is used, as compared with that required when the work is largely hand labor, is as shown below.

Operation	Hours per Acre by Hand	Hours per Acre by Machinery
Cutting	7.2	1.2
Tedding	3.7	0.5
Raking	3.7	0.0
Cocking	1.9	0.0
Loading and hauling	1.8	0.9
Unloading	1.8	0.9
Storing in the mow	1.0	0.5
Total	21.1	4.0

696. Measuring Hay in Stacks and Mows. It often is necessary to estimate the tonnage of hay in stacks, though at best, methods of estimating hay are somewhat inaccurate and wherever possible the hay should be weighed. First, it is necessary to determine as accurately as possible the volume of the stack, and second, the number of cubic feet of the particular hay in the stack required to weigh a ton.

In determining the number of cubic feet in a stack a method which has often proved valuable is that known as the Quartermasters' Rule. In using this method, add together the width of the stack and its over,—that is, the distance from the ground on one side, over the top to the ground on the other side; divide the sum by 4 and multiply this result by itself. The final result, multiplied by the length of the stack, gives the volume in cubic feet. This number divided by the number of cubic feet per ton gives the number of tons in the stack.

Another rule, called the F-O-W-L rule, which has been found somewhat more accurate, has been devised by the United States Department of Agriculture. In this method a factor F is used, which takes into account the varying shapes of stacks, and varies from 0.25 to 0.37. The factor F is multiplied by the overthrow (O), by the width (W), and this product by the length (L). With ricks of different shapes the following factors have been determined:

.For ricks three-fourths as tall as they are wide:
1. Narrow (cross section nearly triangular), F = 0.25
2. Moderately full, F = 0.28
3. Very full-sided, F = 0.31

For ricks as tall as wide:
4. Very narrow (cross section nearly triangular), F = 0.28
5. Moderately full, F = 0.31
6. Very full-sided, F = 0.34

For ricks one and one-fourth times as tall as wide:
7. Very narrow, F = 0.31
8. Moderately full, F = 0.34
9. Very full, F = 0.37

In measuring round stacks the stack is divided into two portions. This division should be made at the shoulder of the stack. The base portion of the stack may be cylindrical or it may be narrower at the bottom than at the top of the base portion. For the cylindrical base the formula is: The volume = 0.08 × height × circumference squared. If the base is smaller at the ground than at the shoulder the volume is calculated by the formula: Volume = 0.08 × height × circumference at the base × circumference at the shoulder. The volume of the upper portion of the stack is found by the formula: Volume = 0.04 × height × circumference at the base of the top portion squared. These formulas give the volume of hay in the stack. In order to find the number of tons it is necessary to divide by the number of cubic feet per ton.

697. Cubic Feet of Hay per Ton. The amount of hay per cubic foot depends upon the length of time the hay has remained in the stack or mow, the height of the stack or the depth in the mow, the kind of hay (whether legume or grass), the stage of development, the time the plants were cut, and the percentage of moisture in the hay when it was placed in storage. McClure and Spillman [35] found that for mixed timothy and clover which had been stacked less than 30 days, 589.6 cubic feet were required to make one ton; from 30 to 60 days, 581.5 cubic feet; and from 74 to 155 days, 514.9 cubic feet per ton.

Cumings [36] states that native prairie hay in Colorado packs more closely than other hay and that 422 cubic feet is considered a ton.

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[35] McClure, H. B., and Spillman, W. J.—"Measuring Hay in Ricks or Stacks." *U. S. Dept. Agr. Off. Sec. Circ. 67.* 1916.

[36] Cumings, G. A.—"Methods of Handling Hay in Colorado." *Colo. Agr. Expt. Sta. Bul. 281.* 1923.

He also states that for Colorado conditions, alfalfa hay stacked 30 days required 560 cubic feet; 60 days, 540; 90 days, 512; 120 days, 485; and later winter, 450 cubic feet per ton.

Hendry[37] reports that freshly stacked cereal hay varies from 540 to 590 cubic feet per ton. The same hay after 80 days of settling may measure only from 510 to 540 cubic feet per ton, and when old and fully settled as little as 421 cubic feet.

698. Baled Hay. In baling hay the bales vary somewhat in size,[38] ranging from 14 × 18 × 36 in. up to 22 × 28 × 46 in. They are classed by weight into three sizes. Small bales are those weighing between 60 and 100 pounds; medium bales, 100 to 150 pounds, and large bales from 150 to 250 pounds. The various markets demand different types of bales. Small bales are usually tied with two wires and medium bales with three, while large bales are often tied with four or five wires. The small bale is generally preferred.

STUDY QUESTIONS ON CHAPTER XXV

1. What is hay? What are the changes which occur in the curing of hay?
2. How does the moisture content of hay vary? When is hay cured?
3. Criticize this statement: "Hay should be cut in the afternoon as the plant is partially wilted at this time and will cure out more rapidly than when cut in the morning."
4. What method of hay curing would you recommend in unsettled weather? In good curing weather? Explain.
5. What is the function of the leaves in curing hay? Is it vital that leaves be kept alive in order to pump water from the stems? Does this disprove the accepted value of windrowing soon after cutting? Explain.
6. Outline the different ways of handling cured hay with information on relative labor costs.
7. You have hay down in swath and know that it will get wet before it is cured. What will you do? Why?
8. What is the "sweat" of hay? What are its results?
9. How is brown hay made? What is its value in comparison with green-cured hay?
10. Sum up the facts on artificial curing, its practicability and its effect on the quality of the hay.
11. What crops are most easily cured for hay? Why is more labor required in handling some crops than in handling others?
12. How many tons of alfalfa are there in a rick which, at the end of 90 days, is 18 feet high, with an overthrow of 48 feet, a length of 32 feet, and a width of 15 feet. The stack has a moderately rounded top.

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[37] Hendry, Geo. W.—"Cereal Hay Production in California." *Cal. Agr. Expt. Sta. Bul. 394*, p. 154. 1925.

[38] Carrier, Lyman—"Hay." *The Book of Rural Life.* Vol. 4, p. 2530. Bellows-Durham Co. Chicago. 1925.

APPLICATION ASSIGNMENTS ON CHAPTER XXV

1. There is no dew at 8:00 A.M. and you could start cutting your alfalfa. However, you are told the plants will have less water and will cure more quickly if you wait until 2:00 P.M. What will you do? Why?
2. On a hot, dry day you cut 5 acres of alfalfa at 8:00 A.M. Knowing that rains were predicted for the next day how will you handle the crop in curing? Why?
3. You have barely finished cutting when a rain cloud approaches and you know it will rain in an hour or so. What will you do? Why?
4. You have hay in the windrows which is thoroughly wet. How will you handle it?
5. At 3:00 P.M. your hay barely rustles when forked, and you estimate that it contains from 30 to 34 per cent of moisture. Rains are predicted during the night. What will you do? Why?
6. A load of hay left on your wagon overnight was so hot in the morning that you could scarcely hold your hand on it. Why? What will you do?
7. Good No. 2 Alfalfa hay is worth $22.00. You are offered brown-colored hay of good aroma and free of molds for $15.00 per ton. Will you buy it? Why?
8. You expect to market the second crop from your alfalfa. What factors influence the method you will use in handling the crop?
9. A rick of alfalfa 90 days old, of average shape, 36 feet long, 18 feet wide and with an overthrow of 42 feet, is offered to you for $75.00. Hay of equal grade is worth $20.00 per ton. Will you buy it? Why?

CHAPTER XXVI

PASTURE MANAGEMENT

Pasturing is usually thought of as one of the least intensive means of utilizing land. The usual rent value per acre of land in pasture is much below that of ordinary tillable land and in most sections of this country pastures have largely been crowded off of tillable land. This is not true in some other sections of the world, notably England, where climatic conditions particularly favorable to grass, combined with various tillage practices, the liberal use of fertilizers, and the seeding of complex mixtures has resulted in yields from pasture land which compare favorably, from the standpoint of net cash return, with those from tilled crop land.

Fig. 124.—Sows with pigs on alfalfa pasture. *Compare alfalfa with rape as a pasture for hogs. Compare with Kentucky bluegrass. With red clover.*

699. Possible Returns from Permanent Pasture. White and Holden,[1] in Pennsylvania, determined the yield of crude protein and of total digestible nutrients obtained from 4 acres of pasture as compared with that from 4 acres in a rotation of corn, oats, wheat, and hay. The same fertilizer treatments and in general the same soil types were used. They found that, when well fertilized, 4 acres of pasture averaged 1986 pounds of digestible crude protein and 8535 pounds of total digestible nutrients, as compared to a yield of 799 pounds and 10,096 pounds respectively, produced on 4 acres in the grain rotation.

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[1] White, J. W., and Holden, S. J.—"The Development and Value of Kentucky Bluegrass Pasture." *Pa. Agr. Expt. Sta. Bul. 195.* 1925.

700. Important Pasture Crops. In general, the regions east of the Great Plains and north of the cotton belt have four major pasture crops,—Kentucky bluegrass, white clover, redtop, and timothy. In the cotton belt, particularly in the eastern section, there are three major crops used for pasture,—Bermuda grass, Carpet grass, and lespedeza. From the eastern edge of the Great Plains on west across the United States the pasturage consists mostly of native grasses. Information about the chief pasture grasses of the United States and their relative importance is reported in Table *700a.*

700a. Relative importance of pasture crops.

	Relative Importance (Piper)	Length of Life	How Spread	Wt. Seed per Bu.	Seeding Rate per Acre Lbs.	Yield Hay Tons	Yield Seed Bu.
Kentucky bluegrass.	35	Perennial	Seed & root stalks	14	20	.66	15
White clover	10	Perennial	Seed & root stalks	60	4		7
Bermuda	8	Perennial	Seed & root stalks	36	5	1.0	
Timothy	7	2 to 6 yr.	Seed	45	15	1.34	5
Redtop	7	Short Perennial	Seed & root stalks	14	10	.8	2
Carpet grass	3	Perennial	Seed & root stalks	18			
Orchard grass	2	Perennial	Seed	14	20	1.0	8-12
Lespedeza	2	Annual	Seed	25	20	2.5	5-12
Johnson grass	2	Perennial	Seed & root stalks	28	15	1.0	
Brome grass		Perennial	Seed & root stalks	14	20	1.5	10-25
Italian rye grass		Biennial	Seed	20	30	1.5	25
Perennial rye grass..		Short-lived Perennial	Seed	20	30	.6	12-25
Meadow fescue		Perennial	Seed	25	20	1.25	8-12
Tall oat grass		Perennial	Seed	10	40		20

701. Palatability of the Pasture Grasses. White *et al.*[2] state that cattle show a preference for the common pasture grasses in the following order: brome, Kentucky bluegrass, meadow fescue, timothy, orchard grass, redtop.

Sarvis[3] listed the grasses of the Great Plains area in order of their palatability as follows: blue grama (which is often called buffalo grass), big bluestem, western needle grass, prairie June grass, tall grama grass, little bluestem, prairie rush grass, big sand grass, porcupine grass, and wire grass. He states that the wire grass is the last grass the cattle will take when forced to graze a short range, and that when cattle start to eat the bunches of this grass, it is a good indication that they are out of other feed.

Piper cites work at Washington in which horses preferred brome grass to orchard grass and red clover mixed, or to tall oat grass, or to mixtures of 11 standard grasses.

At the Idaho Station, sheep showed the following order of choice: orchard grass, meadow fescue, brome grass, perennial rye grass, tall oat grass.

At Ottawa, Canada, cattle showed a marked preference for brome grass over timothy and red clover; at Huntley, Montana, white clover and brome grass, then, in order, meadow fescue, orchard grass, and perennial rye grass.

Gibb[4] states that in Scotland orchard grass takes first place as the most essential grass in pasture mixtures. It stands supreme in productiveness, and in well managed grass lands from the beginning of March till the end of September its edible quality is very high. He states that it is the almost universal belief among graziers that white clover excels all other pasture crops in palatability and nutritive quality. He states that wild white clover is preferred, ordinary white clover being second. Next in order are the late flowering red clovers, broad red clovers (mammoth clover), and then alsike. While alsike is the least palatable of the clovers all clovers are more palatable than any of the grasses.

702. Seeding Down Pastures. It is a common practice in the corn belt to seed pasture mixtures with oats, pasturing the oats in the early stages. Seedings intended for permanent pasture are quite commonly seeded with small grains, cut for hay the first two years and then pastured in subsequent years.

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[2] White, E. J., *et al.*—"Pastures in New York." *N. Y.* [*Cornell*] *Agr. Expt. Sta. Bul. 280.* 1910.

[3] Sarvis, J. C.—"Effect of Different Systems and Intensities of Grazing on the Native Vegetation at the Northern Great Plains Field Station." *U. S. Dept. Agr. Bul. Dept. 1170.* 1923.

[4] Gibb, J. "Palatability and Nutritive Qualities of Pasture Plants." *1926 Res. Ann. of McGill and Smith, Ltd.* Ayr, Scotland.

Wiggans[5] at the New York Station compared various grass crops alone and with clovers, through a two-year period. He concludes that meadows should practically never be seeded to grasses alone even if a pure stand of grass is desired. A better stand of pure grass will be obtained the second year and will remain down longer in good condition if the land is seeded to grass and clover than if it is seeded to grass alone. Where the land is adapted to red clover, this will yield more in a mixture with timothy than will alsike. It is doubtful if redtop should be generally included in meadow mixtures although it is well suited for growth under conditions too wet for timothy. In the seeding of meadows the use of more than 20 pounds per acre of any mixture is generally wasteful. Fifteen pounds per acre is probably ample where conditions are favorable for obtaining a stand.

FIG. 125.—Percheron mares and colts on good pasture. *Having in mind the climatic and soil conditions, from what seeding can you expect the most satisfactory results as a general pasture? What seeding will give the best results as a pasture for horses? For hogs? For sheep?*

703. Mixtures Recommended for Pasture. Pasture crops are usually seeded in mixtures. Wolfe[6] found that for Virginia a mixture of pasture grasses such as Kentucky bluegrass, orchard grass, redtop, and white clover was better than any one of the plants grown alone. On the whole, the yield of pasturage was from 40 to 65 per cent that of the yield of the same mixtures harvested as hay.

Wiggans[7] found that when used as a meadow on soil of average fertility, the length of life of orchard grass, tall oat grass, and bluegrass was indefinite, but that timothy, redtop, meadow fescue, English rye grass, and brome grass when seeded in mixture with blue-

[5] Wiggans, R. G.—"Various Factors Influencing the Yields and Duration of Life of Meadow and Pasture Plants." *N. Y. [Cornell] Agr. Expt. Sta. Bul. 424.* 1923.

[6] Wolfe, T. K.—"Yield of Various Plants in Different Series when Pastured and for Hay." *Jour. Amer. Soc. Agron.* Vol. 18, No. 2, p. 384. 1926.

[7] Wiggans, R. G.—"Various Factors Influencing the Yields and Duration of Life of Meadow and Pasture Plants." *N. Y. [Cornell] Agr. Expt. Sta. Bul. 424.* 1923.

grass were soon crowded out by the bluegrass. This applied to pasture management as well as to meadow management, except that bluegrass and orchard grass were the only grasses that remained under pasture conditions and the other grasses were replaced more quickly by the bluegrass than under meadow management. Wiggans reports that from 50 to 100 per cent as much feed value is obtained by pasturing as by harvesting for hay, depending upon the kind of grass used. Pure bluegrass yields as much when harvested as pasture as when cut for hay.

Miller and Hutcheson[8] make the following recommendations for the Ozark region of Missouri. For the better soils of the region: (1) Kentucky bluegrass, 8 pounds; orchard grass or timothy, 6 pounds; red clover, 2 pounds; white clover, 2 pounds; or (2) Kentucky bluegrass, 8 pounds; timothy, 5 pounds; redtop, 4 pounds, and alsike clover, 2 pounds. For gravelly soils: (1) orchard grass, 8 pounds; Kentucky bluegrass, 5 pounds; red clover, 3 pounds; or (2) orchard grass, 8 pounds; Kentucky bluegrass, 5 pounds; redtop, 4 pounds; red clover, 2 pounds, and white clover, 1 pound. On the very driest soil at all suitable for pasture: (1) orchard grass, 10 pounds; redtop, 5 pounds; red or mammoth clover, 4 pounds; or for a less costly application, (2) orchard grass, 10 pounds; red or mammoth clover, 5 pounds.

For permanent pastures in Oregon and Washington Hunter and Thompson[9] recommend for the northern Pacific coast region the seeding of a mixture consisting of Italian rye grass 8 pounds; orchard grass, 5 pounds; Kentucky bluegrass, 4 pounds; red clover, 4 pounds, and white clover, 1 pound.

In the following recommendations made by Tabor and Crabb,[10] for the coastal plains regions and the cut-over pine lands of the South, the first figure given is when the crop is sown alone, the second when sown in mixture. All figures are pounds per acre. Carpet grass, 10 and 2 to 5; Dallis grass, 10 and 2 to 5; Bermuda grass, 5 and 2 to 3; white clover, 5 and 1 to 2; redtop, 10 and 2 to 5; lespedeza, 25 and 5 to 15; orchard grass, 14 and 4 to 10; burr clover (in the burr), 6 to 10 bu. per acre.

Fisher[11] of Indiana recommends 4 pounds of alsike clover and 6 pounds of timothy for clay and loam soils. This mixture is general in the eastern part of the corn belt, the Kentucky bluegrass and white clover coming in voluntarily as the land is pastured. The second mixture recommended is alsike clover, 4 pounds; white clover, 1 pound; Kentucky bluegrass, 8 pounds, and timothy, 6 pounds. He states that the latter is a more expensive mixture but that in two years it will make a good pasture which will last a lifetime. The soil must be sweet. A mixture adapted to slightly sour soil is alsike clover, 3 pounds; red clover, 1 pound; Kentucky bluegrass, 6 pounds; timothy, 5 pounds; and redtop, 4 pounds. For muck soils he recommends timothy, alsike clover, and Kentucky bluegrass, 6, 4, and 8 pounds, respectively. On sandy soils, alsike clover, alfalfa, sweet clover, and redtop, 4, 4, 4, and 5 pounds, respectively.

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[8] Miller, M. F., and Hutchison, C. B.—"Grass Investigations in the Ozark Uplands." *Mo. Agr. Expt. Sta. Bul. 108*, pp. 137-138. 1913.

[9] Hunter, D., and Thompson, H.—"The Utilization of Logged-off Land for Pasture in Western Oregon and Western Washington." *U. S. Dept. Agr. Farmers' Bul. 462.* 1911.

[10] Tabor, P., and Crabb, A.—"Pasture Soils of Georgia." *Ga. State College Agr. Ext. Bul. 240.* 1921.

[11] Fisher, M. L.—"Pastures for Indiana." *Ind. Agr. Expt. Sta. Circ. 132.* 1926.

Piper[12] summarizes information with reference to pasture mixtures, stating that the best permanent pasture grasses in the humid regions of North America come in spontaneously: (1) In the timothy regions, on rich moist soils Kentucky bluegrass and white clover; on low wet soils redtop; on poor, upland soils Canada bluegrass, redtop, and white clover; (2) for the cotton belt, for clay land Bermuda grass, lespedeza, and burr clover; and for sandy land carpet grass. It is suggested that for a more or less temporary element other seeds should be included in seeding new pasture as follows: where the soil of the region is suitable for Kentucky bluegrass, add white clover, timothy, and either Italian or perennial rye grass. Where the soil is wet and the region suitable for redtop, add white, and alsike clover. Where the soil is poor upland, in the north, use redtop, Canada bluegrass, white clover, and sheep fescue. Where Bermuda grass thrives, add lespedeza, white clover, burr clover, and Dallis grass. Where carpet grass predominates, the addition of Dallis grass, lespedeza, and often burr clover are helpful.

In addition to the grasses mentioned, orchard grass is nearly always desirable because it furnishes the earliest pasture. Southward, tall oat grass is very useful. On the sandy lands along the coast northward, sheep fescue and meadow fescue will often grow to the practical exclusion of other grasses.

704. Temporary Pastures. Temporary pastures may be designated as those designed to carry the animals for only a part of the growing season. Such temporary pastures are usually made by seeding annual crops. In pasturing such seedings, care must be used as the animals are inclined to trample if turned on to large areas at one time. For this reason it is a common practice to turn animals into only small portions of a field and when that is fed off to move them to other parts of the field. Elaborate systems have been worked out,

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[12] Piper, C. V.—*Forage Plants and Their Culture*, p. 106. The Macmillan Company. New York. 1924.

704a. Planting table of forage crops for hogs. Indiana.

Crop	Date of Sowing	Method of Sowing	Rate of Sowing per Acre	Time from Sowing Until Ready for Use	Approximate Length of Time Crop Affords Pasture	Remarks
Rape	April 1 to July 10	Rows or broadcast	2 to 6 lbs.	6 to 8 weeks	4 weeks	Can be pastured several times. Renews growth after being grazed.
Cowpeas	May 25 to July 15	Rows or drilled solid	½ to 1½ bushels	80 to 100 days	4 to 6 weeks	
Soybeans	May 20 to July 15	Rows or drilled solid	½ to 1½ bushels	70 to 90 days	4 to 6 weeks	
Canadian field peas	Mar. 29 to Apr. 30	Drilled or broadcast	1 to 1½ bushels	6 weeks	3 to 5 weeks	Should be sown with oats. Of most value in northern counties.
Rye	August or Sept.	Drilled or broadcast	1 to 1½ bushels	Late autumn Early spring	4 to 6 weeks	August sown rye furnishes good autumn pasture. Earliest spring pasture.
Oats	Mar. 20 to Apr. 10	Drilled or broadcast	2 to 3 bushels	5 to 6 weeks	4 to 6 weeks	With Canadian field peas can be sown as late as May 1.
Vetch	July 1 to Sept. 15	Drilled	40 to 60 lbs.	April and May following year	4 to 6 weeks	
Crimson clover	July or August	Broadcast	10 to 12 lbs.	8 weeks	3 to 4 weeks	If not winter killed, will furnish good spring pasture. Of doubtful value.
Sorghum	May 10 to June 15	Rows or drilled	15 to 45 lbs.	6 to 8 weeks	4 to 6 weeks	
Root crops	May 1 to 30	Rows	4 to 8 lbs.	4 months	According to quantity	Best for storing for winter feed.
Artichokes	Autumn or spring	Like potatoes	10 to 15 bus.	Following autumn	According to quantity	Can be pastured either in autumn or spring when once established.
Pumpkins	May 15 to June 15	Hills	4 to 6 lbs.	120 days	According to quantity	

which give a sequence of temporary pasture crops throughout the year. Crops which are commonly used for temporary pastures are the small grains, rape, vetch, clovers, peanuts, cowpeas, soybeans, velvet beans, chufas, Sudan grass, and the sorghums. Many other crops may be used at certain periods of their growth.

With the use of temporary pastures the selection of crops will depend upon the section of the country and upon the type of livestock by which the pastures are to be used.

Fisher and King[13] have suggested various means of handling crops as pasture for hogs in Indiana, giving the method of seeding, the rate of seeding per acre, the time ready to use, and the approximate length of the pasture period in Table *704a*.

Seedings made with the intention of pasturing for only one, two, or three years are also referred to as temporary pastures, when considered in comparison with seedings of perennial grasses intended to be left down indefinitely. Such seedings are made on land which enters somewhat regularily into the rotation. Crops used extensively are timothy, red clover, alsike, and sweet clover.

705. Intensity of Grazing the Northern Great Plains. Sarvis[14] reports the results of a grazing experiment in central North Dakota in which a 100-acre pasture was grazed at the rate of 10 acres per steer; a 70-acre pasture, 7 acres per steer; a 50-acre pasture, 5 acres per steer, and a 30-acre pasture, 3 acres per steer. The average gain per head during the five-month pasture period ranged from 294 pounds on the 70-acre pasture to 180 pounds on the 30-acre pasture. The 100-acre pasture was undergrazed; the 70-acre pasture was grazed at approximately the right area per steer for maximum gain, under a system of continuous grazing; the 50-acre pasture was overgrazed and was not large enough to allow the steers to make maximum gains, while the 30-acre pasture was severely overgrazed. Overgrazing of pastures results in limiting the growth of some of the most palatable grasses and in increasing the least palatable. Sarvis states that the quantity of foliage cover removed annually by grazing varied from 51 per cent in the 100-acre pasture to 98 per cent in the 30-acre pasture. To avoid injury to the vegetation under a system of continuous grazing, from 15 to 25 per cent of the foliage cover must remain on the pasture throughout the grazing season. Sarvis states that the native pastures deteriorate when grazed too early in the spring with continuous grazing, or when overgrazed. All of these factors can be controlled. Each year a number of trials were made to improve the native herbage by seeding cultivated forage plants in the native sod without breaking. The results show that it is very nearly impossible for plants to grow in a vegetation of such density as on this pasture.

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[13] Fisher, M. L., and King, F. G.—"Supplementary Pasture Crops." *Ind. Agr. Expt. Sta. Circ. 35.* 1912.

[14] Sarvis, J. T.—"The Effect of Different Systems and Intensities of Grazing on the Native Vegetation in the Northern Great Plains." *U. S. Dept. Agr. Bul. 1170.* 1923

706. Type of Grass and Intensity of Grazing. Piper[15] states that under heavy grazing nearly all tufted or bunch grasses are greatly weakened and with overgrazing the plants die out. With creeping grasses and other plants, such as white clover, the pasture may be overgrazed in the sense that the animals do not get sufficient feed, but not in the sense that the plants are injured. Animals prefer the short, fresh growth and avoid the older leaves and stems unless driven to them by hunger. It is an illusion that tall grass in a pasture furnishes reserve pasturage as, under humid conditions at least, cattle will never eat it unless driven by starvation. He states also that undergrazing of creeping grasses is positively harmful to the pasture.

In the West where the native grasses are tuft or bunch grasses, deferred grazing is sometimes practiced. By this method pastures rest for one season so that the surviving plants produce a seed crop. The animals are then turned in to graze. The animals help to scatter the seed of such plants.

Rotation grazing is pasturing sections of the pasture at different times of the year so that the grasses of each type will have an opportunity to produce seed every year or so.

707. Yield and Composition of Grasses when Cut for Hay and when "Pastured." At the Virginia Station[16] one series of plots was cut for hay in the usual manner while, to represent pasture conditions, the growth on a duplicate series was harvested with a lawn mower, keeping the grasses cut reasonably close throughout the season. Yields per acre when cut for hay and when cut with the lawn mower are shown in Table *707a*.

Ellett and Carrier[17] report that the yield of dry matter from permanent bluegrass sod kept clipped with a lawn mower was in inverse proportion to the number of times it was cut during the growing season but that the decrease in the percentage of protein in the grass when allowed to mature is sufficient to more than counterbalance the increase in weight of dry matter when considered from the standpoint of protein alone.

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[15] Piper, C. V.—*Forage Plants and Their Culture,* p. 112. The Macmillan Company. New York. 1924.

[16] Wolfe, T. K.—"The Yield of Various Pasture Plants at Different Periods When Harvested as Pasturage and as Hay." *Jour. Amer. Soc. Agron.* Vol. 18, No. 5, p. 383. May, 1926.

[17] Ellett, W. B., and Carrier, L.—"The Effect of Clipping on Grasses." *Jour. Amer. Soc. Agron.* Vol. 7, No. 2, p. 87. Mar.-Apr., 1915.

707a. Yield of various seedings when harvested as "hay meadow" and as "pasture." Virginia.

Crop	Average		Per Cent of Hay Yield When Cut as Pasture. 3-Year Av.
	Hay	Pasturage	
Kentucky bluegrass	1,733	1,017	60.3
Canada bluegrass	1,733	993	62.4
Orchard grass	5,813	3,130	57.1
Orchard grass, redtop	3,733	1,462	40.2
Orchard grass, redtop, alsike clover	4,720	1,877	44.1
Orchard grass, redtop, perennial rye grass	4,960	1,480	34.0
Kentucky bluegrass, white clover	3,400	1,200	44.0
Kentucky bluegrass, timothy, redtop, red clover	7,333	1,897	29.4
Perennial rye grass	4,027	1,483	45.7
Italian rye grass	3,707	2,252	93.1
Rhode Island bent grass	3,760	1,453	43.0
Meadow fescue	3,600	1,130	35.8
Sheep's fescue	3,907	2,377	65.1
Red fescue	4,853	2,213	59.5
Tall meadow oat grass	5,960	2,763	30.8

Woodman [18] studied the nutritive value of young grass and states that the dry matter in such grass should be considered a concentrated food as it is high in protein and remarkably digestible. The pasturage from April to June contained from 21 to 27 per cent crude protein while hay from similar plots had 9 per cent. The pasturage had 77.85 per cent digestible protein while the hay had only 56 per cent. He says that the ration of young grass is unbalanced and that a carbohydrate concentrate should be fed with it.

Piper [19] cites work at the Michigan Station in which a plot of orchard grass cut 7 times during the season with a lawn mower, yielded 29 pounds of dry hay, and a similar plot cut 4 times, 60.9, while the third plot, not cut until in bloom, gave 112 pounds of hay. In timothy the yield for 8 cuttings was 15.76 pounds, and for a single cutting when in bloom, 172 pounds.

708. The Renovation of Permanent Pasture Land. Cook [20] has reported that in order to effect permanent improvement of West Virginia pastures it will be necessary to follow the practice of keeping the stock off the pasture until after the grass has made a good growth in the spring. In addition to this an application of clover and grass seed with acid phosphate may possibly be given to bare portions of pasture. Under certain conditions lime in addition to fertilizers may produce further improvement, although in most tests where lime has been applied to permanent pastures it has given negative results. Harrowing, sowing clover and grass seed, and liming gave negative results, though marked improvement was noted from the application of a complete commercial fertilizer along with the three other treatments mentioned. The use of acid phosphate and reseeding on a thin pasture gave equally as satisfactory results as complete fertilizer with reseeding and at a much lower cost.

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[18] Bruce, A. B.—"The Composition and Nutritive Value of Young Grass," by Dr. Woodman. *The Jour. Min. of Agr.* Vol. 34, p. 205. 1928.

[19] Piper, C. V.—*Forage Plants and Their Culture*, p. 105. The Macmillan Company. New York. 1924.

[20] Cook, I. S.—"West Virginia Pastures." *W. Va. Agr. Expt. Sta. Bul. 177.* 1922.

Schuster[21] states that under Delaware conditions renovating old pastures is usually an expensive and unprofitable proposition. He states that when pasture land becomes unproductive it usually pays to plow up the pasture and reseed it when the conditions are such as to make this possible. When the renovation of an old pasture is to be attempted the first step is the destruction of the weeds by the use of the mower, followed by a light application of manure to the barren patches, disking, and reseeding.

Stevenson, Forman, and Brown[22] at the Iowa Station report results indicating the advisability of reseeding on permanent bluegrass pastures after the ground has first been disked. Plots disked and reseeded produced at the rate of 2.26 tons of air dry material per acre from two cuttings during the season when plots disked but not reseeded produced at the rate of 1.39 tons.

709. Woodland and Open Pastures. Welton and Morris[23] comparing the herbage of woodland and of open pastures found that the woods pasture contained 32 per cent more weeds and yielded 85 per cent less dry matter than the open pastures, also that pound for pound of actual bluegrass the woodland pasture contained 22 per cent less total nutrients than that from the open pasture. The light in the woods pasture was 76 to 96 per cent less than that in the open field, the evaporation 29.5 per cent less and the temperature 13.4° F. lower.

710. Brush Pastures. The control of sprouts and underbrush in woods pastures has often been an expensive operation in starting and maintaining grass land. Helm,[24] of the Missouri Station, states that the use of goats is without question the cheapest and most satisfactory method of controlling sprouts. In heavy brush the number of goats used varies from 4 to 7 head per acre. After the ground has once been clear 1 animal should control from 3 to 5 acres. Helm also recommends cutting sprouts back by hand or with a sprout cutter in July and August. Another effective method of controlling sprouts is burning. On timber land the fire is destructive to the timber and repeated burning will reduce the stand of such valuable pasture plants as orchard grass and Japan clover.

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[21] Schuster, G. L.—"Management of Meadows and Pastures." *Del. Agr. Expt. Sta. Bul. 130.* 1922.

[22] Stevenson, W. H., Forman, L. W., and Brown, P. E.—"The Pasture Problem in Iowa." *Iowa Agr. Expt. Sta. Circ. 89.* 1924.

[23] Welton, F. A., and Morris, D. H.—"Composition from Woodland and from Open Pastures." *Jour. Amer. Soc. Agron.* Vol. 18, No. 2, p. 237. 1926.

[24] Helm, C. A.—"Meadow and Pasture Management in the Ozark Region of Mo." *Mo. Agr. Expt. Sta. Bul. 234.* 1925.

711. Burning Over Pasture Land. Hensel[25] conducted experiments in burning pastures at the Kansas Agricultural Experiment Station. Areas were burned over each year in comparison with similar areas not burned. In the early part of the season there was considerably more growth of grasses on burned areas than on those unburned. In midseason there was more grass on burned areas but the difference was not so great as early in the season and as the season advanced the difference became less and less. It is stated that the burning did not decrease the total number of grass plants, as is generally thought to be the case, but the number of sedges decreased on the burned areas. There was a tendency for the sedges to increase on the unburned plots. Burning caused a change in the composition of the grass type on the experimental area. Big Bluestem decreased on the burned area and showed a decided increase on the unburned area, while the effect on Little Bluestem was exactly the reverse. Kentucky bluegrass increased rapidly on the burned area. There was a decrease

FIG. 126.—Shropshire sheep on a good bluegrass pasture. *Is there any difference in the feeding value of grass in a woodland pasture as compared with grass in an open pasture?*

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[25] Hensel, R. L.—"The Effect of Burning on the Vegetation in Kansas Pastures." *Jour. Agr. Res.* Vol. 23, No. 8, p. 642. Feb. 24, 1923.

each year in number of weeds on the burned plot, while on the unburned plot the weed population increased. The mean minimum temperature was 4.1° F. higher on the burned plot than on the unburned plot and this probably explains the more rapid early growth on the burned area. Hensel concludes that studies so far conducted have failed to show that burning is injurious.

Piper [26] reports South African experiments to the effect that the soil temperature of the burned areas is higher both day and night than that of the unburned areas. Profound differences appear as to the relative abundance of different species on the burned and unburned areas. The species which increase on the burned lands are relatively inferior as forage. Under the South African conditions burning seemed desirable only on lands which tend to produce bushy shrubs.

FIG. 127.—Holstein cattle on sweet clover pasture. *Does sweet clover pasture taint the milk from cattle? What are the chief advantages in seeding sweet clover for pasture and what are the main objections? What precautions can be taken to reduce the danger from bloat on sweet clover and other legume pastures?*

712. Bloating of Stock on Pastures. When animals are grazed on succulent, palatable pastures such as alfalfa, red clover, and rape, they are often subject to bloat, particularly cattle and sheep. Sanfoin and Japan clover are said never to cause bloating. Sweet clover was formerly thought to be comparatively safe from this standpoint but in recent years much bloat on this clover has been reported. If succulent, palatable grasses or legumes are to be pastured off, care should be used in handling the stock. Cattle should not be turned on such pasture when they are hungry. When on such pasture they should have access to water, salt, and a supply of hay or straw, and many experienced graziers are of the opinion that when once accustomed to such pasture the stock should be left on continuously, rather than intermittently.

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[26] Piper, C. V.—*Forage Plants and Their Culture*, p. 120. The Macmillan Company. New York. 1924.

STUDY QUESTIONS ON CHAPTER XXVI

1. What characteristics give a plant value as a pasture crop?
2. What particular qualities and characteristics make Kentucky bluegrass so important as a pasture grass? What are its greatest shortcomings?
3. Rank the different pasture grasses according to their relative palatability.
4. In seeding down a pasture would you use a single grass or several? Why?
5. Give the seeding you would recommend in making a permanent pasture in your section.
6. How do the different types of pasture compare in carrying capacity?
7. What governs the relative degree of intensity of grazing which is desirable? Explain.
8. How does the yield of a particular crop which is pastured compare with that of the same crop harvested as hay? Give examples.
9. What practices are recommended in the improvement of permanent pastures?
10. Is it advisable to burn over pastures during either the late fall or early spring?
11. What is the cause of bloat? Why do some crops bloat stock more than others? What can be done to decrease the danger of bloat?

APPLICATION ASSIGNMENTS ON CHAPTER XXVI

1. You find it necessary to increase the acreage of permanent pasture on your general live stock farm. How will you make the seeding and what grasses or clovers will you include in the mixture?
2. There is a considerable growth of weedy grasses on your pasture at the end of the pasture season. Will you burn off this growth and if so when? Explain.
3. Your permanent bluegrass pasture, which is on land that cannot be plowed, has become noticeably low in productivity. What will you do to improve this pasture?
4. You have succeeded in establishing a good permanent pasture. How will you manage this pasture so as to keep it as productive as possible?

5. In buying seed for a pasture, you are offered a "pasture mixture" at a price very much below that which you would need to pay if the different grasses and clovers which you wish to include are purchased separately. Will you buy the "pasture mixture"? Explain.
6. Your farm is all tillable. You are considering whether to seed a portion down as a permanent pasture or to rely on temporary pastures. What are the factors you will consider in coming to a decision? What will you do?

CHAPTER XXVII

ALFALFA AND SWEET CLOVER

ALFALFA

There probably are very few field crops, if any, in which a larger proportion of those who do not grow the crop are interested than alfalfa. Its high feeding value and productivity are well recognized as well as the fact that there are certain requirements which must be met if the crop is to be grown with marked success. (See Figure 31)

713. History. Media or Persia is believed to be the region of the original culture of alfalfa, the wild alfalfa of that region closely resembling the cultivated types. Pliny states that alfalfa was introduced into Greece from Media at the time of the Persian wars about 490 B.C.[1] Its rapid development in the United States dates from 1854, when it was introduced into California from Chile. Earlier introductions had been made into the eastern part of the country, but it was not until these introductions were made into California that the acreage increased materially. The alfalfa crop is commercially important in the western part of the United States, the Mediterranean region, Australia, Argentine, Chile, Peru, South Africa, and central Asia.

714. Climatic Adaptation. Alfalfa grows well with irrigation in the extremely high temperatures of Arizona and other parts of the world. It does not seem to be limited by heat, in regions of low humidity; however, high temperatures combined with high humidity are very injurious to the crop. Certain strains of alfalfa are able to stand severe winter conditions. The most cold resistant strain seems to be the Siberian strains of sickle alfalfa (*Medicago falcata*). With reference to moisture, alfalfa is especially adapted to semi-arid regions. Wet weather seems to be more injurious than dry weather. In moist sections alfalfa does best on well-drained, deep soil, high in lime. In semi-arid sections it will succeed on almost any soil except those which are extremely alkali. **(163) (183) (187)**

715. Classification and Growth Habit. Alfalfa belongs to the family *Leguminosae* and the genus *Medicago*. The wild alfalfa belongs to the species *falcata*, while the cultivated varieties to the species

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[1] Stewart, George—*Alfalfa Growing in the United States and Canada*, pp. 20-43. The Macmillan Company. New York. 1926.

sativa. Alfalfa is a perennial, and the stems, which bear short, leafy branches, arise from the crown and usually vary in number from 5 to 20. The succeeding growth after the crop has been cut comes from buds which appear near the bottom of the old culms. The new buds start their growth about the time the plant is beginning to flower. The plant varies from 18 inches to 3 feet in height. The typical flower color of the common alfalfa is purple and those of the wild alfalfa yellow, while in particular strains of common the flowers vary from purple to almost white. The flower produces a spiral pod with many seeds.

Oakley and Westover [2] state that the varieties and types of alfalfa may be divided into groups as follows: (1) The common group. This includes the ordinary, purple-flowered, smooth alfalfa of which there are numerous regional strains, generally grown throughout the western part of the United States. These are usually given the name of the section in which they have been developed, such as Kansas grown, Utah grown, Montana grown, and Dakota grown seed. (2) The Turkestan group. This includes alfalfas which have been developed in Turkestan. These differ from the common alfalfas of this country in that they are somewhat shorter and more spreading in habit of growth and are slightly more hairy. (3) The variegated group. This includes alfalfas originated from crosses between common alfalfa and the yellow-flowered species. They are winter hardy and the flower color varies from light and dark purple to blue, green, smoky, and white. Among these are the Grimm, Cossack, Baltic, Canadian Variegated, Hardigan, Ladak and Sand Lucerne. (4) The non-hardy group. This includes rather distinct varieties which are very susceptible to low temperatures. They are, in general, very erect in habit of growth, recover quickly after cutting, and have a long growing period. Peruvian and Arabian varieties are members of this group. (5) The yellow-flowered group. This includes various forms of the yellow-flowered species of *Medicago falcata*. These are easily distinguished from members of the other groups by the yellow flowers and crest or sickle-shaped pods.

716. Adapted Varieties. Extensive studies on the cold resistance of alfalfa have been made at Dickinson, North Dakota. Brand and Waldron [3] report that when grown under uniform conditions 2 strains from Africa, 1 from Spain, 2 from France, and 4 from Arabia killed 100 per cent; 2 strains from Utah, 1 from Italy, and 5 from South America, more than 90 per cent; 2 from Russia, 5 from Germany, 2 from Mexico, and 11 from various parts of the United States, between 80 and 90 per cent; 12 from Turkestan and 3 from Nebraska, between 70 and 80 per cent; 3 from Montana, 65 per cent; 2 from Canada, 45 per cent, and 3 from Mongolia, 33 per cent. A strain of Grimm alfalfa from Fargo, North Dakota, killed 2.8 per cent; another strain of Grimm from Clearwater, Minnesota, 7.0 per cent; and Turkestan from Highmore, South Dakota, 9.2 per cent.

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[2] Oakley, R. A., and Westover, H. L.—"Commercial Varieties of Alfalfa." *U. S. D. A. Farmers' Bul.*, 757. Revised Ed. 1920.

[3] Brand, Charles J., and Waldron, L. R.—"Cold Resistance of Alfalfa and Some Factors Influencing It." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 185*. 1910.

Kiesselbach and Anderson [4] report a comparison of common, Cossack, Baltic, Grimm, Canadian Variegated, Sand Lucern, and Turkestan alfalfas, in which the stand survival after several years was estimated in per cent as follows: 72, 89, 85, 83, 69, 13, 81, respectively. The yields of hay in tons per acre were 4.47, 5.09, 4.97, 4.72, 4.66, 4.05, and 4.16 as an average for 4 years.

Overpeck and Conway [5] tested Hairy Peruvian, Common, Grimm, and Turkestan for a period of 5 years at the New Mexico Station. The average yield in tons per acre was 6.97, 4.98, 4.85, and 4.17, respectively.

Arny [6] reports a comparison of various strains of alfalfa, among which Minnesota Grimm, Montana Grimm, Turkestan, Kansas Common, and Nebraska Common were compared. The yields were as follows, respectively: 4.03, 3.90, 3.14, 2.38, and 2.76, as a four-year average.

717. Root Structure of Alfalfa Varieties and Strains. Carlson [7] reports the study of the effect of the different kinds of soil structure on alfalfa roots. He found that in compact soil all varieties and strains develop branch roots, while in open soils tap roots predominate. He found also that Grimm alfalfa is characterized by broad, deep-set crowns and somewhat more numerous fibrous roots than common alfalfa. Northern and southern grown common alfalfa have similar root features,—small, high-set crown and few fibrous roots. Baltic and Siberian compare favorably with the characteristic Grimm alfalfa.

Garver [8] made an extensive study of the types of roots of hardy and non-hardy plants. He states that the most hardy hybrids and yellow alfalfa varieties can be told from the least hardy varieties with accuracy, but that intermediate groups are not sufficiently different from one another or even from some forms of the non-hardy

[4] Kiesselbach, T. A., and Anderson, Arthur.—"Alfalfa in Nebraska." *Nebr. Agr. Expt. Sta. Bul. 222.* 1927.

[5] Overpeck, J. C., and Conway, W. T.—"Alfalfa Variety Tests." *N. Mex. Agr. Expt. Sta. Bul. 152.* 1926.

[6] Arny, A. C.—"Alfalfa Aids Progress in Minnesota." *Minn. Univ. Agr. Ext. Spec. Bul. 104.* 1926.

[7] Carlson, F. A.—"The Effect of Soil Structure on the Character of the Alfalfa Root Systems." *Jour. Amer. Soc. Agron.* Vol. 17, No. 6, p. 343. June, 1925.

[8] Garver, Samuel—"Alfalfa Root Studies." *U. S. Dept. Agr. Dept. Bul. 1087.* 1922.

or from the hardy yellow alfalfa to identify them accurately. While there appears to be some relation between the gross root structure and degrees of winter hardiness, this is believed to be incidental and not causal.

Steinmetz,[9] working with Kansas common and Grimm, found that resistance to cold appears to develop in the roots as winter approaches and disappears with the approach of spring. Temperatures taken at the surface of the soil beneath the snow indicated that a covering of snow provides ample protection for alfalfa plants from killing as a result of low temperatures. **(126)**

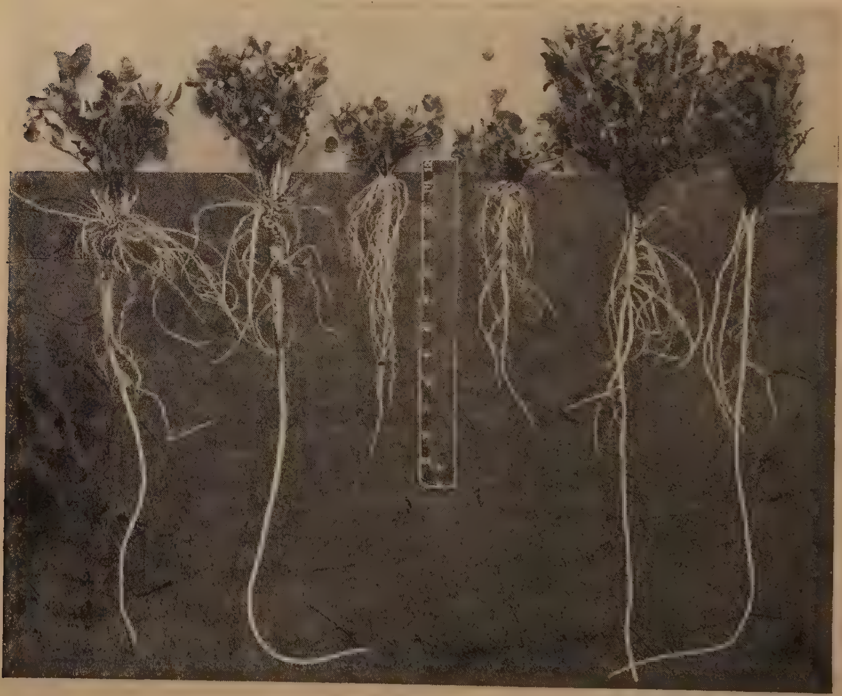

FIG. 128.—Representative plants of sweet clover, red clover and alfalfa showing the relative root growth one year from seeding. *With favorable soil conditions, except for severe drouth, are seedings of sweet clover, red clover or alfalfa most likely to fail? What are the advantages and disadvantages of each crop when used in a short rotation?*

718. Inoculation of Alfalfa. Unless the proper alfalfa bacteria are present in the soil, the alfalfa must be artificially inoculated at the time of seeding if satisfactory yields are to be secured. The related plants which cross-inoculate with alfalfa have been indicated.

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[9] Steinmetz, Ferdinand H.—"Winter Hardiness in Alfalfa Varieties." *Minn. Agr. Expt. Sta. Tech. Bul.* 38. 1926.

(197) (198) (199) In general, in inoculating alfalfa any of the standard cultures and methods used for other crops will apply.

Alway and Nesom[10] found on a lime deficient, sandy soil, that when the land had been limed well in advance of the seeding, the use of artificial cultures was as effective as a heavy application of soil in securing satisfactory inoculation of the alfalfa or sweet clover, but that when this land had not been limed the soil transfer method was by far the most effective. Increasing the amount of culture to many times the usual rate did not make it as effective as the soil transfer method.

The alfalfa bacteria are not generally distributed east of the Missouri river. Reports from studies made by most of the stations indicate that when the crop is being seeded on a piece of ground for the first time, the only safe procedure is to inoculate.

719. Liming for Alfalfa. It has been pointed out that alfalfa cannot be grown with any degree of success on soils deficient in calcium and that most soils in the eastern states and many of those in the corn belt must have applications of lime to correct the acid condition of the soil. **(188) (189)**

720. Method for Seeding. Various methods are used in seeding alfalfa. It may be seeded in the spring either alone or with a nurse crop such as early oats or barley, or on winter wheat or rye. It is also seeded alone later in the season on land freed of weed seed by repeated cultivation. Methods of seeding and the time of seeding will depend very much on the climatic conditions of the particular locality.

Alfalfa cannot compete successfully with weeds when young. The seedbed should be free from weeds regardless of the method of planting used. There is no one best method of seedbed preparation.

Alfalfa seed, as with the clovers, should not be planted too deep. One-half to three-fourths of an inch, in general, is sufficiently deep; although on light soil satisfactory stands may be secured when planted slightly deeper than this. In heavy soils the seeding should be shallow. Seeding may be done either with the small seed attachment of the ordinary grain drill or it may be seeded with various types of broadcasting devices such as the Cyclone seeder, the horn seeder, the endgate seeder, or in fact may be seeded broadcast by hand.

721. Rate of Seeding Alfalfa. Williams[11] seeded alfalfa at the rate of 5, 10, 15, 20, and 25 pounds per acre at the Ohio Station. The average yields for a 3-year period were 4.5, 4.57, 4.36, 4.3, 3.86 tons, per acre, respectively. **(321) (322) (323)**

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[10] Alway, Frederick J., and Nesom, George H.—"Inoculation of Alfalfa on Lime Deficient Sandy Soils." *Minn. Agr. Expt. Sta. Tech. Bul. 46*, p. 4. 1927.

[11] Williams, C. G.—"Alfalfa Culture." *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 2, No. 6, p. 176, June, 1917.

Cocke[12] tested alfalfa seeded at the rate of 10, 15, 20, and 30 pounds per acre in Virginia through a 3-year period. While the yields of hay and weeds were 2.55, 2.51, 2.57 and 2.48 tons per acre, weeds made up 45, 35, 22, and 4 per cent of the weight, respectively.

Oakley and Westover[13] recommend seeding from 20 to 25 pounds in the humid sections; 20 pounds per acre in the Great Lakes region and in the western part of the humid area, and 12 pounds under dry farming conditions, although they suggest that 4 to 5 pounds sometimes give good stands under these conditions. They recommend 15 to 20 pounds under irrigation.

Woodward[14] reports rate and date of seeding tests for alfalfa in Montana under dry-land conditions. Alfalfa was seeded at the rate of 4, 6, 8, 10, 12, 14, and 16 pounds per acre. The average yields of hay for an 8-year period were 1.03, 1.08, 1.13, 1.19, 1.17, 1.21, and 1.25 tons, respectively. He states that while an increased yield of alfalfa was obtained as the rate of seeding increased up to 16 pounds, yet the differences in yields obtained are insignificant above 10 pounds and that when the seedbed is properly prepared, 10 pounds of alfalfa seed per acre is considered sufficient.

At the Manitoba Station[15] alfalfa was seeded at the rate of 5, 7½, 10, 12½, 15, 17½, and 20 pounds per acre. The maximum yield of hay as a 7-year average was obtained from seeding 7½ to 10 pounds per acre. The heavier rates of seeding seemed to actually decrease the yield.

In northwestern Saskatchewan, Tinline[16] compared alfalfa seeded broadcast and drilled. Seed drilled at the rate of 10, 15, and 20 pounds yielded 2260 pounds, 1700 pounds and 1440 pounds per acre, respectively, as a 2-year average. When seeded broadcast at the same rate the yields were 1160 pounds, 1120 pounds and 1080 pounds in cultivated rows 24, 30, and 36 inches apart.

722. The Stage to Cut Alfalfa for Hay. The usual recommendation has been to cut alfalfa in the early bloom stage (one-tenth in bloom) or when new shoots have begun to come from the crown of the plant.

Publications from Ontario (*Dept. Agr. Bul. 111*), Kansas (*Bul. 214*), Minnesota (*Bul. 80*), Arkansas (*Bul. 175*), Iowa (*Bul. 137*),

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[12] Cocke, R. P.—"Experiments with Alfalfa in Eastern Virginia." *Va. Agr. Expt. Sta. Bul. 247*. 1926.

[13] Oakley, R. A., and Westover, H. L.—"How to Grow Alfalfa." *U. S. Dept. Agr. Farmers' Bul. 1283*. 1922.

[14] Woodward, N. F.—"Experiments with Alfalfa and Grasses at the Judith Basin Substation." *Mont. Agr. Expt. Sta. Bul. 152*. 1923.

[15] Sigfusson, S. J.—"Alfalfa in Manitoba." *Canada Dept. of Agr. Bul. N. S. 54*. 1925.

[16] Tinline, M. J.—"Hay and Pasture Crops in Northwestern Saskatchewan." *Canada Dept. Agr. Bul. N. S. 40*. 1924.

Ohio (*Bul. 181*), Arizona (*Bul. 73*), and California (*Circ. 87*) recommend that the crop should preferably be cut in the early stage of bloom but do not present experimental evidence.

Singleton[17] found that alfalfa cut when one-half in blossom outyielded that cut when one-fourth in blossom by approximately one ton per acre and produced almost as much hay as that cut when three-fourths in blossom.

The Illinois Experiment Station[18] reports that alfalfa cut in the full bloom stage was entirely winter killed on all plots, while the same variety, South Dakota No. 12, when cut in the one-tenth bloom stage came through the winter in good shape. *The last cutting at the full bloom stage was made later in the fall than the last cutting at the one-tenth bloom stage.*

At the Washington Station,[19] as a 6-year average, cutting alfalfa when three-fourths in bloom, yielded 6.86 tons of hay as compared to a yield of 6.71 tons for cutting at the one-half bloom stage, and 5.83 tons for cutting at the one-fourth bloom stage.

In 1908 the Kansas Station[20] reported cutting alfalfa when in the first bloom, one-tenth, half bloom and full bloom with respective yields of 4.7, 5.4, 4.5, and 6 tons per acre, calculated on a uniform basis of 17 per cent moisture. Four crops were received from each stage of cutting except the full bloom stage, where three were obtained.

In 1925, Salmon[21] *et al.* report stage of cutting tests at the Kansas Station continued through an 8-year period with yields as shown below.

722a. Stage of cutting alfalfa. Kansas.

STAGE OF CUTTING	8-YR. AV. YIELD OF HAY—TONS PER ACRE		TOTAL	STAND AT START PLANTS PER ACRE	STAND AT END PLANTS PER ACRE
	Pure Alfalfa	Grass			
				(1914) 000 Omitted	(1922) 000 Omitted
Bud stage	2.65	0.59	3.24	562	129
Tenth bloom	3.21	0.20	3.41	534	85
Full bloom	3.43	0.08	3.51	447	159
Seed stage	2.91	0.02	2.93	427	197

[17] Singleton, H. P.—"Irrigated Alfalfa in Washington." *Wash. Agr. Expt. Sta. Bul. 209.* 1926.

[18] Burlison, W. L., and Hackleman, J. C.—"Alfalfa Cut in Full Bloom State Is Killed Out." *Ill. Agr. Expt. Sta. Ann. Rpt. 39*, p. 28. 1925-26.

[19] Singleton, H. P.—"Irrigated Alfalfa in Washington," *Wash. Agr. Expt. Sta. Bul. 209.* 1926.

[20] Ten Eyck, A. M.—"Alfalfa Hay: Its Making, Handling, and Marketing." *Kans. Agr. Expt. Sta. Bul. 155*, p. 239. 1908.

[21] Salmon, S. C., Swanson, C. O., and McCampbell, C. W.—"Experiments Relating to the Time of Cutting Alfalfa." *Kans. Agr. Expt. Sta. Tech. Bul. 15.* 1925.

To find the residual or lasting effect of the stage of cutting on the Kansas plots, all the plots were cut at the same date in 1922 and 1923. In 1922, the yields were 2.0, 2.3, 2.9, and 2.3 tons per acre for the bud, tenth bloom, full bloom and seed stages, respectively. In 1923, the yields were 2.5, 2.6, 3.1, and 3.0 tons, respectively. Tests of the quality of hay produced in the later stages of cutting show beyond reasonable doubt that the feeding value of alfalfa hay decreases materially with delay in cutting, the best hay for feeding beef steers being that cut in the bud stage and the poorest that allowed to reach the seed stage. The amount of hay required to produce a pound of gain was nearly two and one-half times as great for the latter as for the former.

Graber [22] *et al.* report the results of stage of cutting on the root reserves of alfalfa. They found that the vigor and productivity of alfalfa were greatly reduced, weed infestation was augmented, and both winter and summer mortality of alfalfa plants was accentuated by frequent and early removal of the top growth. Where removals of the top growth were sufficiently frequent the vigor of the succeeding growth decreased rapidly and a heavy summer mortality of the alfalfa plants occurred in the field. The amount of winter injury was closely correlated with the frequency of the removal of the top growth and the amount of top growth permitted to remain uncut during the fall and winter months.

Yields of top growth of alfalfa may be larger for a short period with frequent and early cutting, but inevitably, with such treatment, the potentiality of the plants, in producing both top and root growth, is so lowered that fewer and more mature cuttings have far outyielded more frequent and less mature removal of top growth. They state that the reason for the retardation of root and top growth of alfalfa plants and their ultimate death from cutting frequently is due primarily to the inability of the plant to elaborate organic food reserves in sufficient quantity to provide for adequate translocation to and storage of such reserves in the root for the development of the roots as well as that of the top.

Kiesselbach and Anderson [23] from a time of cutting test continued through a 4-year period conclude that, from the combined standpoint of acre yield and quality of hay and permanency of stand, it would seem that under average Nebraska conditions the most desirable practice is to cut for hay when the flowers are from one-tenth to one-half in bloom and for practical purposes harvesting may ordinarily extend over this period without materially affecting results.

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[22] Graber, L. F., *et al.*—"Organic Food Reserves in Relation to the Growth of Alfalfa and Other Perennial Herbaceous Plants." *Wisc. Agr. Expt. Sta. Res. Bul. 80*, p. 123. 1927.

[23] Kiesselbach, T. A., and Anderson, Arthur—"Alfalfa in Nebraska." *Nebr. Agr. Expt. Sta. Bul. 222.* 1927.

723. Grass in Mixtures with Alfalfa. Woodward[24] found that alfalfa alone produced 2037 pounds and alfalfa and brome grass 1924 pounds as a 6-year average in Judith Basin, Montana.

In Manitoba, Sigfusson[25] compared various alfalfa-grass mixtures with alfalfa alone. Of the mixtures, the timothy, western rye, alfalfa mixture ranked first in yield with the brome, western rye, alfalfa mixture a close second. Alfalfa crowded out most of the grasses and was crowded out by brome. The yield of alfalfa alone was equal to the highest of the mixtures.

FIG. 129.—An extra cutting of alfalfa in a given season often results in a material difference in the vigor of growth and of the yield the following year. *At what stage of growth is it best to cut alfalfa for hay and how many cuttings can be had per year?*

Arny[26] reports that as a 4-year average alfalfa alone yielded 2.34 tons, while alfalfa and timothy yielded 2.19 tons in Minnesota as a 4-year average.

Moore and Graber[27] recommend that beginners in alfalfa growing may well add from ⅕ to ¼ as much timothy to the seeding as the weight of the alfalfa seed. The timothy grows well in case the alfalfa is thin or is winter killed.

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[24] Woodward, N. F.—"Experiments with Alfalfa and Grasses at the Judith Basin Substation." *Mont. Agr. Expt. Sta. Bul. 152.* 1923.

[25] Sigfusson, S. J.—"Alfalfa in Manitoba." *Canada Dept. Agr. Bul. N. S. 54.* 1925.

[26] Arny, A. C.—"Alfalfa Aids Progress in Minnesota." *Minn. Univ. Agr. Ext. Spec. Bul. 104.* 1926.

[27] Moore, R. A., and Graber, L. F.—"Wisconsin's Opportunity with Alfalfa." *Wisc. Agr. Expt. Sta. Bul. 374.* 1925.

724. Pollination of Alfalfa. The alfalfa flower is interesting in that it has an explosive apparatus which when released causes the stigma and anthers to fly up against the standard of the flower, rupturing the stamens and scattering the pollen. This process of releasing the staminal tube is called tripping. Flowers which are tripped artificially and, therefore, self-pollinated, set pods freely. Piper *et al.*[28] report that automatic tripping is a normal phenomenon. Thirty-three out of 57 marked flowers on one plant in Montana became automatically tripped and set 21 pods. Insects are the natural aid in cross-pollination of alfalfa, though rain and wind cause a few alfalfa flowers to become tripped. They state that, at least in the west, automatic tripping with consequent self-pollination probably results in the setting of as many pods as tripping by insect visitors. They found also that crossing of flowers with pollen from other plants produced about 50 per cent more seed than self-pollination.

Waldron[29] planted *Medicago sativa* and *Medicago falcata* together and found that 7.48 per cent of the *Medicago sativa* seed produced hybrid plants, and 42.7 per cent of the *Medicago falcato* seed.

Jardine and Call[30] report that good crops of alfalfa seed are frequently produced in western Kansas, but in central and eastern Kansas profitable seed crops are produced only in the driest seasons.

Martin[31] found that the setting of seed pods in alfalfa is dependent upon the proper functioning of the pollen, germination of the pollen depending upon a proper supply of moisture. If the water supply is either above or below a certain requirement, the pollen does not germinate. The water requirement of the pollen depends upon a certain ratio between the moisture delivered to the stigma and the moisture of the air surrounding the stigma. When the optimum supply of soil and atmospheric moisture for pollen germination is available an increase in the soil moisture, resulting in an increased moisture delivery to the stigma, disturbs the required moisture balance and prevents fertilization.

725. Alfalfa Seed Production. Seed crops of alfalfa are produced occasionally in all parts of the United States. The certainty of the crop is greatest in the West, especially in the Plateau states. The yields in the corn belt run from 2 to 3 bushels per acre, while in the more arid West, 4 to 6 bushels are commonly grown.

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[28] Piper, C., *et al.*—"Alfalfa Seed Production: Pollination Studies." *U. S. Dept. Agr. Dept. Bul. 75.* 1914.

[29] Waldron, L. R.—"Cross Fertilization of Alfalfa." *Jour. Amer. Soc. Agron.* Vol. 11, No. 6, p. 266, Sept., 1919.

[30] Jardine, W. M., and Call, L. E.—"Alfalfa in Kansas." *Kan. Agr. Expt. Sta. Bul. 197.* 1914.

[31] Martin, J. N.—"Relation of Moisture to Seed Production in Alfalfa." *Ia. Agr. Expt. Sta. Res. Bul. 23.* 1915.

Alter[32] studied the weather conditions and alfalfa seed production under Utah conditions. He found that the summer must be quite dry to produce satisfactory crops of seed rather than stem or leaf growth, yet moisture must be ample and timely for filling the seed. Heavy rains must not wash away the pollen. Two or three inches of rain per month from March till June and from one-half to an inch per month in light showers from July to September are desirable. He states that the average period required in the principal seed regions in Utah for the production of a seed crop is about 80 days. The first cutting is taken for hay about June 15 or 20, after which 40 days are required to reach the early blossom stage or cutting time for hay and 40 additional days are necessary for maturing the seed, bringing harvest about September 4 to 9. Through a period of years Utah produced more seed than any other state.

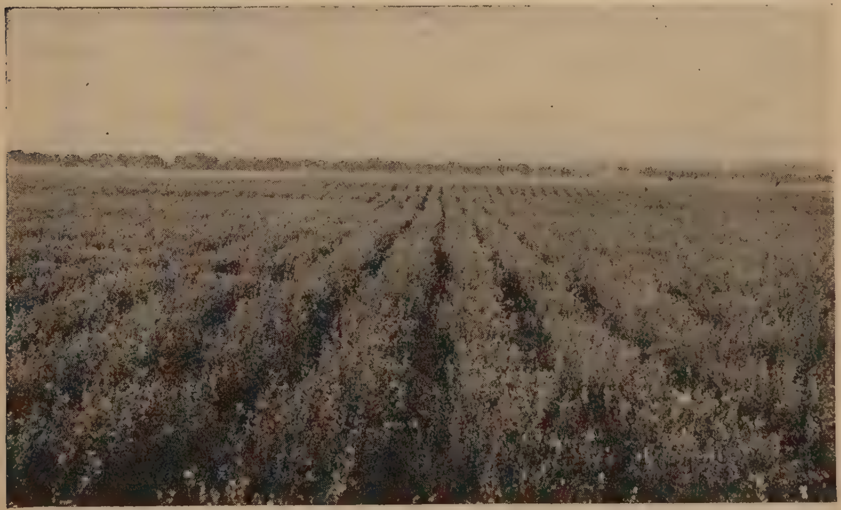

FIG. 130.—Grimm alfalfa planted in rows for seed production at Benkelman, Nebraska. *Under what conditions is it advisable to attempt to get a seed crop from alfalfa? Which cutting is usually taken for seed? Why does common alfalfa ordinarily fail to make a seed crop under humid conditions?*

Blinn[33] finds that for Colorado conditions, a medium quantity of water is needed. He finds also that pasturing off the first growth late in the spring apparently stimulates good seed yields. A thin, uniform stand of plants, one plant about every two square feet, will give maximum results. Dry climatic conditions at high temperature seem to be among the most essential requirements for successful alfalfa seed production.

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[32] Alter, J. Cecil—"Alfalfa Seed Growing and the Weather." *Utah Agr. Expt. Sta. Bul. 171.* 1920.

[33] Blinn, Philo K.—"Factors that Affect Alfalfa Seed Yield." *Colo. Agr. Expt. Sta. Bul. 257.* 1920.

Moore and Graber[34] find that in Wisconsin dry weather, especially during the blossoming season, is necessary in order to raise a crop of alfalfa seed. When drouth prevents a big crop of hay, seed production is at its best.

McClymonds[35] states that it is a common practice in Idaho to start cutting the seed crop when three-fourths of the curls are black. In harvesting, the use of a windrow attachment on the mower is quite common. It throws the seed in rows and out of the way of the team. After windrowing, the crop is piled in small cocks as low and flat as possible. It is desirable to thresh as soon as possible. If threshing must be delayed, the crop is preferably stacked. The alfalfa seed crop is threshed, either with a clover huller or with a grain separator equipped with a recleaner attachment.

726. Uses of the Crop. The major portion of the alfalfa crop is used for hay. It is quite extensively used for pasture for hogs, and in the West, men experienced in handling it find it satisfactory for pasturing other types of livestock as well. Alfalfa has occasionally been used for the production of silage and under certain conditions it might be used as a green manure crop and as a soiling crop.

SWEET CLOVERS

A few years ago sweet clover was generally considered as being not only worthless as a field crop but as one of the bad weeds. An immense amount of publicity favorable to sweet clover has been placed before the public in the last few years, and the popularity of this legume as a field crop is rapidly increasing. Willard[36] states that of the legumes it is at present third in importance in Ohio, being exceeded only by red clover. In Illinois[37] the 1926 acreage was reported at 744,000.

727. Adaptation and Use. Climatically, sweet clover is adapted to practically all of the United States and southern Canada. It is said to withstand more dry weather than alfalfa and can endure wet or poorly drained soils much better than alfalfa. It is not limited with reference to type of soil except that it requires a soil with an abundance of lime. Sweet clover is one of the best legume forage crops to grow on alkali soils. It is now grown extensively from Pennsylvania westward and from Kentucky northward; also, in the black land belt of Alabama and Mississippi.

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[34] Moore, R. A., and Graber, L. F.—"Wisconsin's Opportunity with Alfalfa." *Wisc. Agr. Expt. Sta. Bul. 374.* 1925.

[35] McClymonds, A. E.—"Alfalfa Seed Production in Southern Idaho." *Idaho Agr. Expt. Sta. Bul. 143.* 1926.

[36] Willard, C. J.—"An Experimental Study of Sweet Clover." *Ohio Agr. Expt. Sta. Bul. 405,* p. 3. 1927.

[37] Whiting, Albert L., and Richmond, Thomas E.—"Experiments in Handling Sweet Clover." *Ill. Agr. Expt. Sta. Bul. 285.* 1927.

The sweet clovers are outstanding in their value for pasture and soil improvement. The plant is also used as hay, as a soiling crop, and it can be used for silage. It has also been widely recommended as a bee pasture. **(183) (187)**

728. Varieties and Types of Sweet Clover. The sweet clovers belong to the genus *Melilotus,* four forms of which are commercially important in the United States.

The biennial white sweet clover, *Melilotus alba* also known as Bokara clover, in the first season of growth produces a very large, fleshy, branched root of the tap-root type, and a top growth reaching a height of from 18 inches to 3 feet. The second year the plants make a rapid, vigorous growth from buds at the crown of the root and attain a height of from 4 to 10 feet, branching vigorously if isolated. The flowers are borne in narrow racemes on the ends of the branches and are white in color. The pods usually contain but one seed. The leaves of sweet clover resemble alfalfa in appearance, but are glabrous rather than hairy. All parts of the plant, including the mature seed, contain considerable quantities of cumarin, which gives the plant its characteristic sweet, vanilla-like odor. There are several strains of biennial white sweet clover. One of the most widely known is the Grundy County (Illinois) sweet clover which is a dwarf type maturing 3 weeks earlier than the ordinary type and seldom making a growth of over 4 feet.

Biennial yellow sweet clover, *Melilotus officinalis,* makes a growth very similar to that of the biennial white but has yellow flowers, matures usually about 3 weeks earlier, is finer and leafier, and seldom makes a growth of over 5 feet.

Annual white sweet clover, *Melilotus alba annua* (Hubam clover), is an annual form of *Melilotus alba,* which was isolated from a planting of biennial white by H. D. Hughes of the Iowa Agricultural Experiment Station in 1916. It is believed to have originated in Alabama. When seeded alone it may make a growth of from 5 to 8 feet and mature a crop of seed in 5 months' time. Being an annual, it does not live over winter and is ready to plow for green manure purposes in the fall of the first year.

Annual yellow sweet clover, *Melilotus indica,* is an annual species with yellow flowers. It grows as a weed in wheat fields in the Southwest, where it reaches a height of from 2 to 3½ feet. It is of value as a winter pasture crop in the "black belt" of Alabama and as a winter cover crop in orchards in California. In the central corn belt the plant seldom makes a growth of more than 8 inches or a foot and is mature by the middle of July.

729. Comparison of the Different Types for Cropping Purposes. Of the sweet clovers the use of the annual yellow variety is confined to the South and Southwest. The three varieties which may be used generally in the United States are biennial yellow, biennial white, and Hubam or annual white.

Willard[38] states that in the spring of the second year the top growths of the two biennial clovers are nearly identical until about the first week of June when the yellow comes into bloom and the growth slows up so that the loss of leaves and stems exceeds the growth, while the white sweet clover continues growth for two to three weeks longer, producing a final total yield for the season decidedly higher than that of yellow. This early maturity and smaller yield makes the yellow decidedly inferior to the white for pasture as the white will afford pasture for from 3 to 6 weeks longer than the yellow. The stems of the yellow are smaller than those of the white and cure out more readily for hay. The seed crop of yellow ripens more uniformly and the shorter, smaller stems make it easier to harvest with the binder. The chemical composition of the two is very similar.

McKee[39] states that biennial white sweet clover is the most common variety in Montana but that its popularity is decreasing in favor of the biennial yellow. He states that the biennial yellow has a more spreading or prostrate habit of growth; the leaves and stems are finer, and it matures 1 to 2 weeks earlier than the biennial white. Tests on dry land in the Judith Basin Branch Station indicate that under the conditions there it gives larger yields of seed than the biennial white variety.

The Hubam, or annual white sweet clover, makes a large top growth with a relatively small root development the first season, while the biennial makes a comparatively smaller top growth and a larger root growth. The Hubam clover, being an annual crop, may be safely plowed in the fall of the year of seeding. On the other hand, the biennial sweet clovers if plowed down in the fall of the first year are inclined to renew their growth the following spring, growing as a weed in the crop which follows. The place of the annual white sweet clover has not been definitely determined but it seems to be the best legume available for use as an annual green manure crop to be seeded in small grain and plowed under as green manure in the fall of the year it was seeded. Comparisons between the annual white and the biennial white sweet clover at the Iowa State College indicate that while the top growth of the Hubam clover will be somewhat greater than the first year growth of the biennials, the root growth will be smaller and it will add somewhat less nitrogen to the soil.[40]

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[38] Willard, C. J.—"An Experimental Study of Sweet Clover." *Ohio Agr. Expt. Sta. Bul. 405*, p. 57. 1927.

[39] McKee, Clyde—"Growing and Using Sweet Clover in Montana." *Mont. Agr. Expt. Sta. Circ. 118*. 1923.

Arny and McGinnis[41] found that at the end of the first season of growth the total weight of tops and roots was nearly the same for the annual and biennial. The roots of the biennial, however, made up 51 per cent of the total, while the roots of the annual were but 9 per cent of the total.

They report that on the average there was approximately 25 per cent advantage in favor of the biennial over the annual in the amount of dry matter in tops and roots together and 55 per cent in the total protein content.

Willard and Thatcher[42] report a comparison of Hubam with the biennial white sweet clover, in which their data show that Hubam makes more top growth the first year than the biennial, but that the top growth contains a lower percentage of protein. The biennial makes a much greater root growth than the Hubam and the nitrogen content of the root is higher. The total amount of nitrogen added was much greater for the biennial than for the Hubam clover.

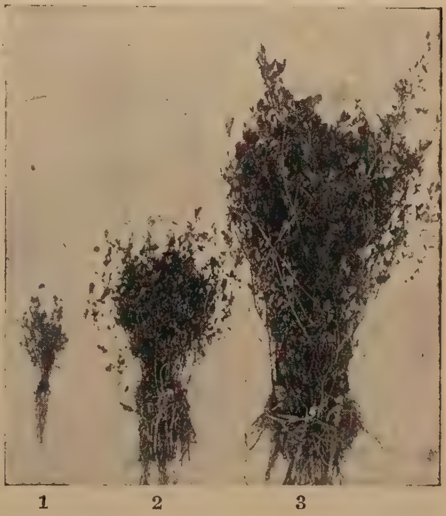

FIG. 131.—There are twenty representative biennial white sweet clover plants in each bundle: (1) no lime and no inoculation; (2) inoculation but no lime; (3) inoculation, with plenty of lime. *Under what conditions is it inadvisable to include sweet clover in rotation in place of red clover? In case the soil is to have an application of limestone, how will you determine the amount required and when and how will it be applied?*

There are a number of strains or varieties of sweet clover which are being compared by the different stations to determine their adaptation to particular localities and to different uses.

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[40] Unpublished Data. *Ia. Agr. Exp. Sta. 1923.*

[41] Arny, A. C., and McGinnis, F. W.—"The Relative Value of the Annual White, the Biennial White, and the Biennial Yellow Sweet Clover." *Jour. Amer. Soc. Agron.* Vol. 16, No. 6, pp. 384-396. June, 1921.

[42] Willard, C. J., and Thatcher, L. E.—"Experiments with Hubam Clover." *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 7, Nos. 1-2, p. 15. 1922.

730. Seeding Sweet Clover. For most uses, sweet clover is seeded with a small grain nurse crop. When put in with spring sown small grains the clover seed is usually broadcast and covered either by disking or by harrowing. With reference to winter wheat and rye, sweet clover is often either drilled crosswise of the winter wheat or rye in the spring, or seeded broadcast and harrowed in, or seeded very early and allowed to freeze in. Sweet clover is not ordinarily seeded alone, although satisfactory results are obtained by seeding alone in the late summer, usually around the middle of August.

Willard[43] compared early oats, late oats, and winter wheat as a nurse crop for biennial white, biennial yellow, and Hubam sweet clover. He concluded in general that the spring grains have been more satisfactory than winter wheat as nurse crops for sweet clover on the soil types used. Barley and early oats such as the Fulghum and Sixty-day were superior to late oats when measured by the stand secured and the growth of the sweet clover in the first year. Willard states also that sweet clover should not be sown alone in the spring unless it is known from previous experience that the soil is free from weeds. When seeded alone without weed competition sweet clover made large yields of dry matter the first year, amounting to 5 tons per acre in one experiment. The recommended rate of seeding in the corn belt is from 10 to 15 pounds. (321) (322) (325)

731. Sweet Clover for Pasture. Sweet clover seeded with small grain is often pastured from late August until the growth is killed in the late fall of the first year of growth and from early spring until late August of the second year, thus giving a long pasture period. The carrying capacity of the sweet clover, that is, the number of head of mature animals an acre of the pasture will support, depends largely upon the soil type and the rainfall. Under favorable conditions from 2 to 3 mature animals per acre is the standard.

Shepperd[44] reports a rather extensive study of sweet clover for pasture under North Dakota conditions. Cattle were forced to eat sweet clover by confining them to it. They ate it fairly well after three days' time during which no other forage was available, but seemed to crave other forage, possibly for variety, until the sweet clover reached the blossom stage of growth. No cases of bloating occurred during the experiment. However, nine out of 20 Northwest farm managers reported slight trouble from bloating. Their report covers observations equivalent to 6000 head of cattle for one season. When brome grass and sweet clover were each grazed at the rate of 2 steers per acre, the sweet clover carried the load while the brome grass was overstocked at least 25 per cent. Cattle in grazing sweet clover ate the coarse, heavy stems of blossoming sweet clover in preference to the leafy new growth. They also appeared to lose their insatiable desire for the other forages when the blossoming stage was reached **(712)**.

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[43] Willard, C. J.—"An Experimental Study of Sweet Clover." *Ohio Agr. Expt. Sta. Bul. 405*, p. 74. 1927.

[44] Shepperd, J. H.—"Sweet Clover—Experiments in Pasturing." *N. Dak. Agr. Expt. Sta. Bul. 211*, p. 57. 1927.

732. Sweet Clover for Hay. One of the requirements for a hay plant is that it be leafy. Willard[45] reports that the percentage of leaves in biennial white sweet clover hay is from 50 to 60 per cent in the fall of the first year but that in the second year it drops rapidly from 50 to 60 per cent early in the season to 25 or 35 per cent as maturity approaches. Willard states that on the basis of the average analysis the fall hay after small grain is superior to any but the very best alfalfa. Sweet clover has a very high calcium content, alfalfa being the only hay which has a comparable amount of calcium in the hay.

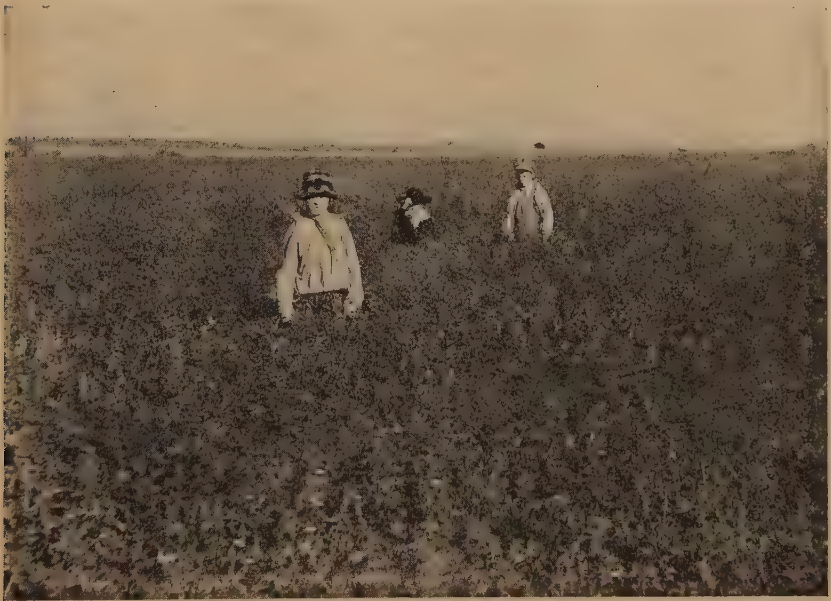

FIG. 132.—Sweet clover seeded with small grain and which produced one and one-half tons of hay per acre in the fall following the removal of the small grain crop. *Does the removal of a hay crop in the fall decrease the value of the sweet clover as a soil improving crop and if so, how much? Under what conditions is it advisable to remove a sweet clover hay crop in the fall of the year of seeding?*

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[45] Willard, C. J.—"An Experimental Study of Sweet Clover." *Ohio Agr. Expt. Sta. Bul. 405,* pp. 65-69. 1927.

733. Effect of Taking a Hay Crop the First Year on the Value for Green Manure. Willard[46] reports as an average of four years at Columbus that by cutting the sweet clover for hay late in September the amount of nitrogen available as green manure in April of the second year was reduced more than one-half. The better the growth made before cutting and the later it was cut the less was the loss. Cutting the clover for hay in the fall delayed the spring growth so that it could not be pastured until two weeks later than that not cut. He states also that sweet clover should never be clipped in August unless it is to clear weeds which would destroy the stand if it were not clipped and then the mower should be set as high as possible.

734. Handling the Crop for Green Manure. Willard[47] reports the nitrogen per acre in the tops, stubble, and roots of sweet clover at various dates.

734a. Time of plowing sweet clover vs. *nitrogen per acre. Ohio.*

DATE OF HARVEST	POUNDS NITROGEN PER ACRE IN			TOTAL NITROGEN PER ACRE
	Tops or Hay	Stubble	Roots	
Sept. 6, 1922	59	..	45	104
Sept. 28, 1922	65	..	72	137
March 31, 1923	15	..	162	177
April 24, 1923	63	..	103	166
May 10, 1923	128	..	75	203
May 24, 1923	134	..	56	190
June 14, 1923	132	11	32	164
July 2, 1923	137	9	15	152
July 19, 1923	119	11	14	133
Aug. 8, 1923	136	10	15	151

Whiting and Richmond[48] (Illinois) state that from the standpoint of nitrate production there is no particular advantage in allowing the sweet clover to grow through the second season except in special cases, because when plowed down in the spring as a green manure it supplies sufficient soil enrichment without sacrificing the use of the land for the crop season. They found that nitrification of both spring and fall plowed sweet clover proceeded rapidly and to such an extent on one field as to furnish nitrates in excess of the requirements of a large corn crop. Spring plowing resulted in a better physical condition of the soil than fall plowing and less labor was required for preparing the land for the crop. More active organic matter was plowed under in the spring and this is one of the most important considerations. Fall plowing of sweet clover is frequently desirable, but until more information is available as to the method of thoroughly killing the crop, spring plowing of the biennial should be the general practice. Early spring plowing gave a high nitrate content at an earlier date than the later plowing. The date of plowing sweet clover in the spring should be decided according to the need of the soil for active organic matter, since the rapidity with which sweet clover decomposes after spring plowing insures prompt nitrification. Light sandy soils and those deficient in organic matter should have the sweet clover plowed as late as is consistent with good soil preparation for the corn crop. Heavy soils, such as clays, loams, and in general those soils which have grown one or more crops of clover, are not likely to be materially affected for corn production by the date of plowing the sweet clover. Available moisture for the corn crop which follows in the rotation should have consideration.

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[46] Willard, C. J.—"Sweet Clover." *Ohio Agr. Expt. Sta. Bimo. Bul.* Vol. 12, No. 4, p. 114. July-Aug., 1927.

[47] Willard, C. J.—"When Should Sweet Clover Be Plowed Down?" *Ohio Agr. Expt. Sta. Bimo. Bul.* Vol. 10, Nos. 3 and 4, p. 43. 1925.

[48] Whiting, Albert L., and Richmond, Thomas E.—"Experiments in Handling Sweet Clover." *Ill. Agr. Expt. Sta. Bul. 285.* 1927.

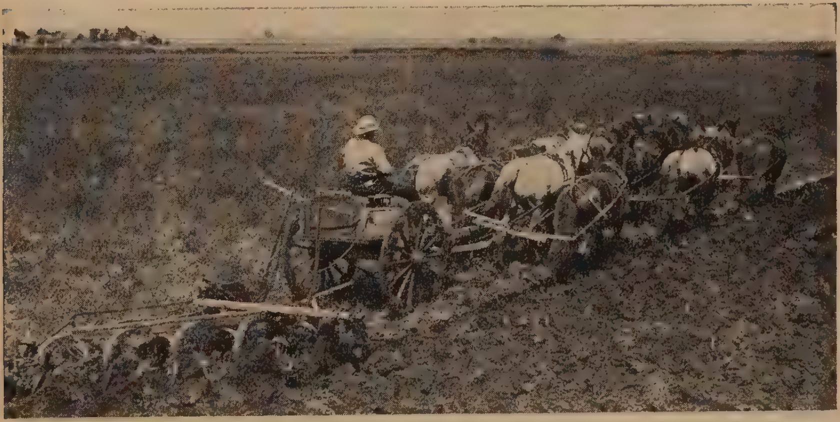

FIG. 133.—Plowing under the remains of a sweet clover crop, pastured during the second year of its growth. *From the standpoint of green manure what is gained by allowing sweet clover to continue through the second year as compared with plowing in the spring of the second year after the clover has made a growth of from eight to sixteen inches? Of the portion consumed by animals when pasturing, what per cent of the nitrogen, phosphorus, potassium, and organic matter is returned to the soil?*

Sears[49] reports that in one comparison when sweet clover was plowed at different dates in the spring, plowing April 1 for green manure produced 14.2 bushels more corn than plowing April 29. An unusually dry spring accounts in part for the difference in yield as the low yielding plots were depleted of their soil moisture by the rapidly growing sweet clover so late in the spring that an uneven stand of corn was obtained. (219)

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[49] Sears, O. H.—"No Gain Found in Plowing Sweet Clover Late." *Ill. Agr. Expt. Sta. Ann. Rpt. 39*, p. 28. 1925-26.

735. Top and Root Development. Willard[50] gives the life cycle of sweet clover somewhat as follows: the first year, after the nurse crop was cut, there was a slow increase in the tops until about September 30. Their weight then remained fairly constant until freezing killed them in the late fall. The roots increased in weight rather slowly until the last of September; then there was a rapid increase, the weight usually doubling between October 1 and winter. In the second year the roots were first very rapidly depleted to build up the tops. The tops grew very rapidly during the spring and summer of the second year and reached their maximum early in July; then the loss of leaves and small stems overbalanced the growth of leaves and the total weight of tops per acre decreased for the last three or four weeks before the death of the plant, which occurred during August. (222)

736. Sweet Clover for Seed. Sweet clover has generally been harvested for seed when the pods were three-fourths brown, cutting with the ordinary grain binder, equipped with pans at the end of the platform canvas and below the deck to catch the shattered seed. The loss from shattering is likely to be excessive unless the crop is cut when the plants are damp from rain or dew. After cutting the crop is shocked and in drying weather is ready to thresh in a week. In threshing, the ordinary grain separator is usually preferred to the clover huller on account of its greater capacity. Yields of sweet clover seed vary rather widely. Five bushels or 300 pounds of cleaned seed per acre is a good average yield.

A machine for harvesting sweet clover seed, which is gaining rapidly in favor, is made by stripping an old binder of everything but the frame and platform and equipping it with a heavy four-slatted reel by means of which the seed is whipped off of the standing plants and back onto the platform where they are caught. The platform is converted into a seed box by building up the back and ends out of light material to a height of five or six feet.

737. Pollination of the Sweet Clover Flower. Kirk[51] found but 0.01 per cent crossing of the yellow-flowered *Melilotus officinalis* on the white flowered plants exposed to the yellow pollen. He[52] reports that *Melilotus alba* is entirely self-fertile and sets seed freely without insects but that the *Melilotus officinalis* is probably unable to set seed satisfactorily unless cross-pollinated by insects.

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[50] Willard, C. J.—"An Experimental Study of Sweet Clover." *Ohio Agr. Expt. Sta. Bul. 405*, p. 36. 1927.

[51] Kirk, L. E.—"Natural Crossing between White Flowered and Yellow Flowered Sweet Clover." *Sci. Agr.* Vol. 9, No. 5, pp. 313-315. 1929.

[52] Kirk, L. E.—"Self-pollination of Sweet Clover." *Sci. Agr.* Vol. 6, No. 4, p. 112. 1926.

Coe and Martin [53] working with the *Melilotus alba* at Ames, Iowa, and at Arlington, Virginia, in 1916 found that less than one per cent of the flowers set seed when not pollinated through the visits of insects. They state that in the United States the honey bee is the most important pollinator of sweet clover.

STUDY QUESTIONS ON CHAPTER XXVII

1. How are the different groups or varieties of alfalfa distinguished from one another? Where are these grown?
2. Do different varieties of alfalfa mix readily when grown in adjoining fields? Explain.
3. In what areas is alfalfa seed production an important industry? Why is the production of seed so important in these areas and not in other sections? Why is so little alfalfa seed produced in the central corn belt?
4. Outline the different methods of seeding alfalfa. Under what conditions would each be recommended?
5. What method and rate of seeding alfalfa is recommended for your locality? Explain.
6. What considerations govern the time for cutting alfalfa or hay? When do you recommend that alfalfa be cut in your section if the crop is to be marketed?
7. What is the most common method of handling a crop of alfalfa for seed?
8. Considering the country as a whole, what are the conditions most important to observe in the successful production of alfalfa?
9. Contrast alfalfa and sweet clover in habit of growth. In general appearance.
10. What are the soil requirements of sweet clover as compared with alfalfa?
11. What are the characteristics of sweet clover which are responsible for the extensive use now being made of this crop, which for so many years was considered a weed?
12. In what way do the sweet clovers differ from one another? For what or under what conditions are the different types to be recommended?
13. Under what conditions would you advise sweet clover for hay? How would you cut and handle the crop for this purpose?
14. Sweet clover seeded for hay was killed with the first cutting in the second year of growth, while sweet clover along the roadside is not killed even with repeated cutting. Explain.
15. Considering a rotation of corn, corn and oats, with sweet clover seeded in the oats, when would you advise plowing the clover? Explain.

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[53] Coe, H. S., and Martin, John—"Sweet Clover Seed." *U. S. Dept. Agr. Dept. Bul. 844.* 1920.

APPLICATION ASSIGNMENTS ON CHAPTER XXVII

1. You are planning to seed 20 acres of alfalfa. You are offered certified Grimm at 45 cents; certified Cossack at 40 cents; government inspected Ontario Variegated at 36; Verified Origin, Dakota 12 at 32; Kansas-Nebraska seed at 30, and Utah-Idaho at 27 cents per pounds. What seed will you buy, having in mind the results secured from the different varieties and their proved adaptation to your particular region. Explain.
2. You can seed your alfalfa in winter wheat this spring or with oats. What would be your method of seeding and covering with each? Which nurse crop will you choose? Why?
3. You were prevented from spring seeding. You have your choice of seeding alone in the early or mid summer on land reserved for the purpose or in the late summer following the removal of a small grain or a hay crop. What considerations will determine the time and method you will use? When will you seed?
4. You decide to use 15 pounds of seed per acre but the seeder puts approximately 18 pounds per acre on the first 10 acres of a 20-acre field. Will you purchase more seed or seed the balance of the field at the rate of 12 pounds per acre? Explain.
5. You have seeded alfalfa in a crop of early oats. A favorable season results in a growth of 15 inches by the first of September. Will you take a hay crop? Explain your decision.
6. Your alfalfa is just begininng to bloom. If you do not cut it now you will not be able to cut it for two weeks, when it will be in full bloom. When will you cut? Justify your decision.
7. Your soil, which is an upland, rather low in fertility, shows a distinctly acid condition. You wish to try sweet clover on this soil. How will you proceed? You do not wish to go to any greater expense than necessary. How will you proceed? Explain.
8. You plan to seed sweet clover to be used for pasture in the fall of the first year and throughout the second year. What kind of sweet clover will you use? Justify your decision.
9. You have a heavy black soil on which you wish to seed sweet clover for green manure purposes. This soil can be plowed in the spring in time to plant corn only with great difficulty if at all. Which of the sweet clovers will you use? Explain.

CHAPTER XXVIII

RED CLOVER AND OTHER CLOVERS

The importance of red clover, mammoth clover and alsike clover has been recognized for many years as is indicated by the extent to which these legumes enter into the crop rotations commonly found throughout a large area.

Red Clover

738. Description. Red clover (*Trifolium pratense*) is a biennial, though under favorable conditions a few plants carry over into the third year. Typical of the biennials, when seeded with small grain the plants usually remain in the rosette form during the first season of growth. Under favorable conditions they may make considerable culm growth and even mature seed during the first season. In the second season the first crop or growth usually flowers in June and the second sometime in August. The crown of the plant remains at or just below the surface of the ground and new growth comes from bud shoots arising at the crown. The plant does not ordinarily make a growth of over 30 inches in height, depending upon the soil and climatic conditions under which it is grown. Each shoot may branch and rebranch, and at the terminus of each branch a flower head may be borne. The seed of red clover are purple, yellow and mottled,—purple and yellow. The seed in each plant are all uniform in color. The seed in the head are borne 1 seed per pod.

The number of seed per head varies rather widely. Pammel and Clark[1] report that the first crop of clover on a certain clay loam in Iowa produced 64.7 seed per head, while on a black loose soil in another section of the state 1.82 seed per head were found. The second crop of clover on a black loam soil at Algona contained 80.4 seed per head, while at Harlan there were 3.9 seed per head.

In general, about 25 seeds per head are developed. The number of flowers per head, according to Pammel, varies from 70 to as high as 150.

739. Pollination. Red clover is usually self-sterile. Numerous investigators have screened red clover flowers, protecting them from all insects, and under such conditions very few and usually no seed are set.[2]

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[1] Pammel, Edna C., and Clark, Clarissa—"Studies in Variation of Red Clover." *Iowa Acad. Sci. Proc.* Vol. 18, pp. 47-53. 1911.

Waldron[3] found that 62.4 per cent of the flowers per head produced seed in the open and but 5.7 per cent when screened. When butterflies and other insects were placed in the netted tents with the plants, 2.3 per cent of the heads set seed; while when bumblebees were placed with the plants, 47 per cent of the heads produced seed. He states that bumblebees are responsible for 95 per cent of the seed produced in North Dakota.

740. Strains and Varieties of Red Clover. Mammoth clover (*Trifolium praetense perenne, Hort.*), also known as mammoth red clover, is sometimes spoken of as a variety of red clover. The seed of the two clovers cannot be distinguished even by the best trained seed analysts and the plants are very similar in habit of growth. However, the mammoth clover makes a larger, coarser growth, and comes to maturity three or four weeks later than red clover. It makes only one crop per year. While the yield of mammoth clover may be greater than red clover the hay is likely to be of poor quality due to its coarse woody growth and the fact that it often lodges badly, the plants deteriorating on the ground before cutting. Mammoth clover is perhaps a little more sure to make a stand and produce a crop on a poor soil and particularly on a sandy soil than red clover.

Many comparisons have been made by the United States Department of Agriculture in coöperation with the different state experiment stations, in a study of regional strains of red clover from various parts of the world. In the past much red clover seed has been imported from Italy. This seed has been found particularly worthless in this country as the plants winter-kill in the northern corn belt states, while farther south they are killed by disease. In the central corn belt no imported clover has been found equal to the domestic strains, while in regions with less severe winters clovers from central Europe have given fairly satisfactory results. The European strains of red clover are almost entirely free of pubescence, while the presence of pubescence is a readily noticeable characteristic of the American strains.

741. Distribution and Uses of Red Clover. Red clover is perhaps the most important leguminous crop grown in America. It is grown chiefly for hay, for which purpose it is commonly mixed with timothy. It is also used extensively in mixtures for short rotation pastures and for green manure. The distribution of red clover and

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[2] Westgate, J. M., and Coe, H. S.—"Red Clover Seed Production: Pollination Studies." *U. S. Dept. Agr. Bul. 289.* 1915.

[3] Waldron, L. R.—"Fertilization of Clover." *First Annual Report of Dickinson Sub-Expt. Sta., N. Dak. Agr. Expt. Sta.,* p. 7. 1908.

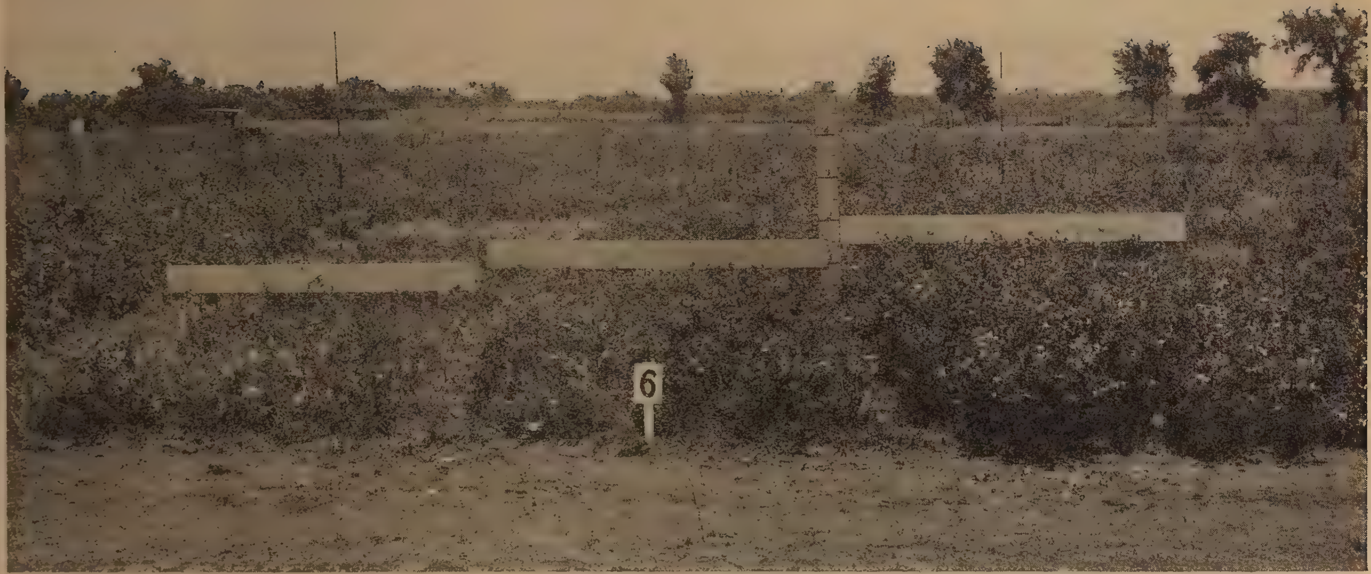

FIG. 134.—A representative growth of Italian red clover, French red clover and domestic American grown red clover at the Iowa Station. *In what part of the country is French red clover equal to domestic clover? In what way can imported Italian red clover seed be identified? French seed?*

timothy in the United States is indicated in Figure 32. The distribution of the crop is almost identical with that of timothy. **(197)**

742. Adaptation of Red Clover. Red clover is admirably adapted as a rotation crop, being seeded with small grain and used for hay one year, and plowed either in the fall or spring for corn, which usually follows. When timothy is seeded in mixture with the clover it may be left down for pasture for one or two years before plowing. Red clover is not as well adapted as sweet clover to seed with small grain to plow under in the spring following the year of seeding, due to the fact that its yield is much lower. The practice of taking one crop of hay in the second year and plowing under the second crop for green manure purposes is widely advocated. **(183) (187)**

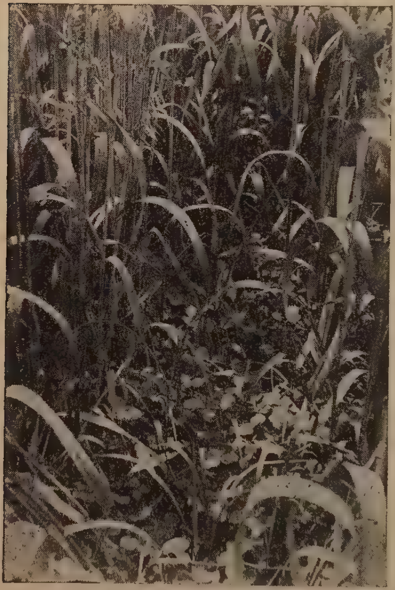

FIG. 135.—A good stand of red clover in oats. *When rainfall is deficient and conditions generally unfavorable for the clover seeding, what practices can be followed in harvesting the small grain, which will be most favorable to the clover seeding?*

743. Method and Time of Seeding. Red clover is ordinarily seeded with the broadcast seeder or the broadcasting attachment on the regular grain drill. Regardless of the method of seeding, red clover seed should be covered shallow. **(321) (322) (325)**

Moore and Delwiche[4] seeded clover from 1/8 inch to 2 inches in depth. The best stands were secured, with the most prompt germination and the longest rooted seedlings, from seeds planted 1/4 to 3/4 of an inch deep. Less than 1/2 of the seeds developed into plants when covered with 1 inch of soil and less than 1/5 when the seed was covered 2 inches in depth.

Red clover cannot compete successfully with weeds and is likely to be choked out, and, therefore, is almost always seeded in a small grain nurse crop. It may be seeded in the winter or early spring on fall sown wheat or rye. The most common method is to seed in the spring with any of the spring sown small grains. It also may be sown between the rows of corn at the last cultivation. This latter method is used to a limited extent in the eastern and northern portions of the red clover belt. The success of such seedings depends largely upon summer rains.

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[4] Moore, R. A., and Delwiche, E. F.—"Growing Clover for Seed and Forage in Northern Wisconsin." *Wis. Agr. Expt. Sta. Bul. 183.* 1909.

When red clover is seeded in the winter or early spring on fall sown wheat or rye it is usually broadcast and either allowed to freeze in or is seeded a little later and is covered by harrowing. When a drill is available even better results are secured by drilling shallow, crossing the grain drill rows. When seeded in the spring with small grain it is usually seeded at the time of planting the small grain. From 8 to 10 pounds of seed per acre is the usual recommendation, with 6 to 8 pounds if seeded in mixture with timothy.

A test of methods of seeding clover at the Ohio Station[5] gave the following results as an 11-year average.

743a. Methods of seeding clover. Ohio.

	Date	Seed Pounds	Yield Tons
Broadcast on frozen ground	March	10	1.68
Broadcast, not covered	April	10	1.80
Broadcast, covered with harrow	April	10	1.73
Broadcast, covered with harrow	April	5	1.74
Grass seed drill	April	10	1.72
Grass seed drill	April	5	1.76

At the Iowa Station success in securing satisfactory catches of clover was found to be more directly associated with the character of the nurse crop than with any other factor. In many cases excellent stands of clover were secured from seedings made with short strawed, early varieties of oats, while seedings made under the same conditions but with taller, later maturing varieties failed. Reducing the rate of seeding the small grain from a third to a half was also found to be desirable. In very unfavorable seasons, with limited rainfall, cutting the nurse crop for hay when in the milk stage in some cases meant the difference between success and failure.

744. Harvesting Red Clover for Hay. McGinnis[6] recommends that red clover should be cut in the full bloom stage and that a timothy and clover mixture should be cut not later than the full bloom stage of the red clover.

Recommendations on the stage to cut red clover vary from young bloom through the full bloom stage until the heads are brown. The greatest amount of digestible nutrients is contained in the crop cut in the full bloom stage. The more nearly mature the plant the easier

[5] Forty-seventh Annual Report." *Ohio Agr. Expt. Sta. Bul. 431*, p. 49. 1929.

[6] McGinnis, F. W.—"Hay Making in Minnesota." *Minn. Univ. Agr. Ext. Spec. Bul. 113*. 1927.

it will be to cure the hay. Work at Illinois indicated the full bloom stage as producing the greatest amount of water-free hay. Similar results have been obtained in Pennsylvania. In Connecticut the greatest yield was obtained when the plants were nearly out of bloom. The early harvest of the first crop is reported to be favorable to the setting of seed in the second crop.

745. Harvesting for Seed. McClymonds and Hulbert[7] recommend that under Idaho conditions red clover be harvested for seed when all of the heads are black. Growing the crop for seed production under irrigated conditions, they recommend that it be pastured in the early spring in order to hold back the growth. They suggest that enough sheep be kept on the field to keep the plants eaten close to the ground until about June 30, after which the animals should be removed. Clipping is used in some sections to even up the growth, particularly where no sheep are available. Sometimes the first crop of clover is taken off for hay and the second crop used for seed.

A light crop is indicated when only 25 to 30 seed are produced per average head, while 60 seed per head indicates a good crop of seed. Much larger yields of seed are secured in Idaho than in the corn and clover belt.

Red clover is commonly cut for seed with an ordinary mowing machine, though a self-rake reaper is used in some sections. In the principal clover-growing sections a special machine called a clover huller is used in threshing out the clover seed. These machines are used when the straw is very dry. The yield of seed is very uncertain and when an examination of the heads indicates a yield of less than 80 pounds per acre, the crop is usually pastured off, cut for hay, or turned under. The principal seed-producing states are Wisconsin, Illinois, Iowa, Indiana, Minnesota, Michigan, and Idaho.

ALSIKE CLOVER

746. Description and Adaptation. Alsike clover (*Trifolium hybridum*) is a short-lived perennial, usually treated as a biennial in this country. It is native to northern Europe, being much grown in Sweden. At one time it was thought generally that alsike clover was a hybrid between red clover and white clover, though at present it is recognized as a separate species. It prefers a cool climate and a moist soil, but it can endure heat better than red clover and has a wider range in this country over which it may be successfully grown than the red clover. It is generally recognized as being a more certain crop for sour or acid soils than red clover and as well adapted to use on poorly drained fields. It has been claimed by some to make a catch under more drouthy conditions than will red clover.

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[7] McClymonds, A. E., and Hulbert, H. W.—"Growing Clover Seed in Idaho." *Idaho Agr. Expt. Sta. Bul. 148*. 1927.

Pieters[8] reports an experiment in which alsike clover was grown in a closed tank in which the water was kept constantly at a level of 3 to 4 inches above the surface of the soil. The growth was good under these conditions.

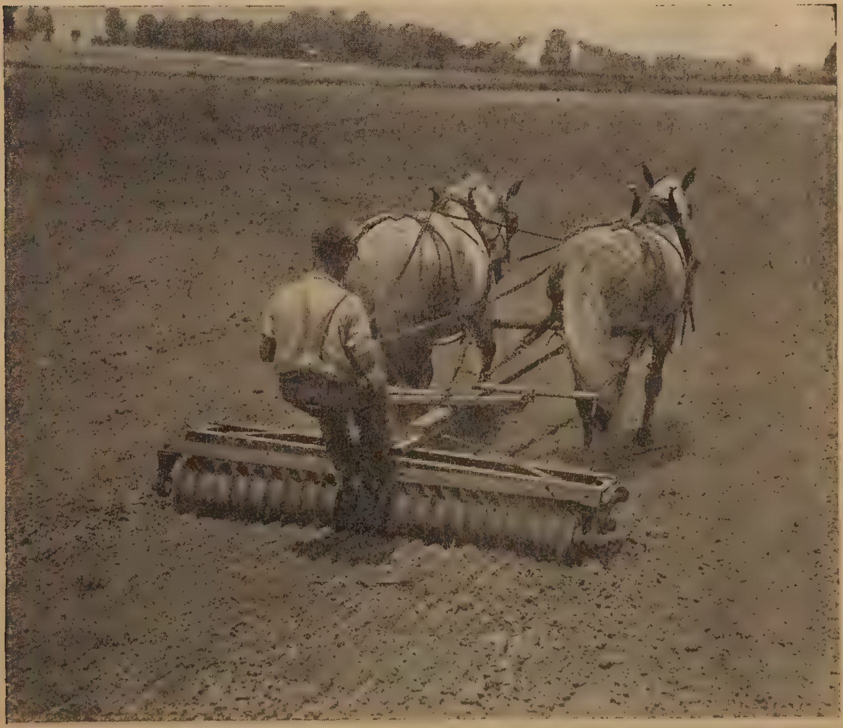

FIG. 136.—The corrugated roller has been found particularly valuable when rainfall is deficient in the spring, to firm the soil following the seeding of small grain and clover.

The stems of the alsike plant are hollow and smooth, or free from hairs. The plants are decidedly leafy, having smooth leaves, the per cent of leaves per stalk being higher than in red clover. The hay consists of around 60 per cent leaves and 40 per cent stems. The flower heads are pink or white in color and are borne on branches which arise from the axis of the leaves. On average soil of the corn belt, alsike clover will grow to a height of 18 to 24 inches, though under the most favorable conditions the stalks may grow from 3 to even 5 feet in length. The culms are weak and the clover is likely to lodge. Timothy is usually planted with alsike to help hold it up. The root system of alsike clover is not so extensive as that of red clover and is inclined to be relatively shallow.

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[8] Pieters, Adrian J.—*Green Manuring*, p. 202. John Wiley and Sons, New York. 1927.

747. Uses of the Crop. Alsike clover makes but one cutting when used for hay under the average conditions of the corn belt. On soils not well suited to red clover one cutting of alsike in some cases has given greater acre yields than two from the red clover. As has been stated, however, it makes no second growth which could be plowed under for soil improvement. **(187) (197)**

Alsike clover has been used rather extensively in areas where red clover will not grow, due to the so-called "clover sickness." Alsike clover is well adapted to growing in mixtures, especially on low or wet soils. It is a very valuable pasture crop and when closely grazed the stems are commonly spreading or nearly prostrate. It is not advisable to seed alone for pasture, owing to the danger of bloat. The method of handling is very similar to that of red clover.

CRIMSON CLOVER

748. Description, Adaptation and Use. Crimson clover (*Trifolium incarnatum*) is a winter annual, native of Europe, where it is grown for green manure and forage in Italy, Austria, France, Germany, and Great Britain, perhaps being more extensively grown in France than in other countries. In the United States it is grown along the Atlantic coast from New Jersey southward and in much of the eastern portion of the cotton belt. Crimson clover is not particular in its soil requirements. However, it will not do well on poorly drained soils, or soils which are low in fertility, or on muck soils. For its best growth it requires a moist climate with frequent rains, particularly in the fall. It winter-kills throughout the northern states and in most of the corn belt. During the fall and winter the plant consists of a rosette of leaves, but early in the spring stems arise from the crown. Each stem is terminated by a long head of scarlet or crimson flowers. The flower heads are slim, cylindrical, and slightly tapering, from 1½ to 2 inches in length. The root system of crimson clover is not so extensive as that of red clover. The flowering head of crimson clover is covered with fine hairs which at maturity become hard and stiff and when fed to horses are likely to form hair balls in the intestines which often result in death. The tendency to form these stiff hairs determines the time to cut crimson clover for hay. It should be cut as soon as the flowers have faded.

Crimson clover may be used for hay, for soiling, for green manure, as a cover crop, or as a pasture crop.

749. Culture of the Crop. In the United States, crimson clover is ordinarily seeded at the rate of 12 to 20 pounds per acre of hulled seed. Quite commonly the unhulled seed is used as it has been shown to give a better stand than the hulled or cleaned seed. When the unhulled seed is used it is much more difficult to handle and should be seeded at about twice the rate of the hulled seed. Seedings are usually made between August 15 and October 1, though in the South it may be seeded as late as November 1. It is commonly seeded between the rows of a cultivated crop and its particular value for green manure comes from the fact that it will make a fair growth in the fall and a very early spring growth. Commonly it can be turned under or even a hay crop removed before the land is fitted for corn in the spring. Crimson clover is seldom seeded in mixtures, although experiments have shown that a mixture with some small grain increases the yield of hay very materially.

White Clover

White clover (*Trifolium repens*) is commonly known as White Dutch Clover. It is a long-lived perennial, native of Europe and Asia, introduced into the United States as early as 1747.

750. Description, Adaptation and Use. White clover thrives best in a cool, moist climate and will grow on almost any kind of soil with sufficient moisture. It grows in practically all parts of America. White clover is long-lived, shallow-rooted, commonly reseeding itself. It has a prostrate, creeping habit of growth, the stems taking root where they come in contact with the ground. This prostrate or creeping habit of growth makes the plant very desirable for pasture purposes, as the growing point of the stem is seldom bitten off by the animal. **(197)**

White clover is used almost exclusively as a pasture plant and in lawn mixtures. Only a small amount of seed is necessary because of its small size. In many sections white clover is not included in pasture mixtures, as it volunteers.

751. Varieties. There are three varieties of white clover which have gained some prominence,—the common white clover of pastures which is naturally distributed generally over the country; a mammoth growing variety from Italy known as the Ladino clover, and the wild white clover of England. The Ladino clover makes two or three times the growth of the ordinary white clover and is of particular value under irrigation, or with abundant rainfall and with mild winters. The wild white clover has been found much more valuable for pasture in England than the white Dutch clover though it is apparently less desirable in this country.

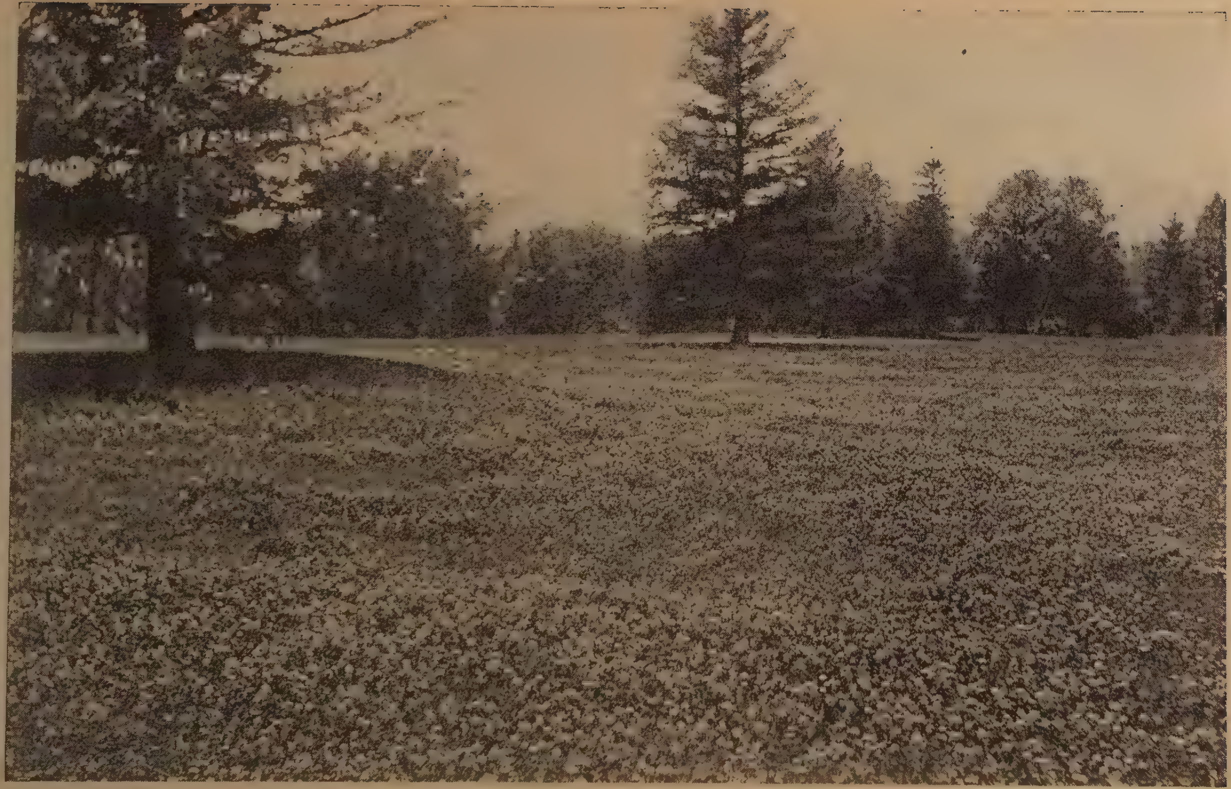

FIG. 137.—A splendid growth of white clover in bluegrass in a "good white clover year." *Does a good growth of white clover insure the presence of the proper bacteria for red clover which may follow in rotation? For alsike clover? For sweet clover? For crimson clover?*

JAPAN CLOVER OR LESPEDEZA

Lespedeza (*Lespedeza striata*)[9] is a summer annual native of eastern Asia, being grown in Japan and various parts of China. It is adapted to the cotton belt of the United States and extends into the southern portion of the corn belt.

752. Adaptation and Description. Lespedeza is decidedly a warm season plant and does not begin to grow until the season is well advanced. In the sections where it is used for hay its best yields are made on low, flat land where it may make a growth of from 20 to 30 inches in height. On poor soils it does not ordinarily grow tall enough for hay, but under these conditions is well suited for pasture. In thin stands the culms are inclined to be prostrate, therefore, for hay production it must be seeded thickly to secure an erect growth with but little branching. The flowers are very inconspicuous and are borne in the axis of the leaves almost sessile to the stem. The plant is capable of reseeding even when pastured closely. The stems of lespedeza are hard and dry in comparison with other clovers and quite commonly the hay crop appears to be stemmy. The root system of lespedeza is not deep but the proportion of roots to tops compares favorably with red clover. **(197)**

Pieters and Van Esceltine[10] have described an early type of lespedeza, known as Korean lespedeza, which can be grown much further north than the lespedeza generally grown in the south.

753. Uses and Culture. Lespedeza is used more extensively as a pasture crop than for any other purpose. Its use for hay is confined to Louisiana, Mississippi, Arkansas, and Alabama.

It is usually seeded with, or on, oats in the spring, the lespedeza crop being harvested in the fall after the oats are removed. Handled in this way lespedeza quite commonly reseeds itself, as the aftermath will produce seed. If harvested for seed, enough seed will shatter to reseed the land. Lespedeza cures out for hay more easily than any other legume, due to the fact that the stems have less moisture in them.

As a pasture crop, lespedeza is remarkable for its ability to grow in competition with Bermuda grass and Johnson grass in the South and also for its ability to grow on poor, sandy and acid soils. It commonly reseeds itself and spreads in pastures. The seed crop is commonly harvested by means of an iron pan which slides behind the cutter-bar of the mower. The top of the pan is corrugated with holes in the bottom of the corrugations. As the plants are cut they fall on top of the box and before being raked off more or less of the seed fall out from the axis of the leaf and are caught in the pan. The yields of seed gathered in this way range from 100 to 300 pounds per acre.

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[9] Carrier, Lyman—"Lespedeza as a Forage Crop." *U. S. Dept. Agr. Farmers' Bul. 1143.* 1920.

[10] Pieters, A. J., and Van Eseltine, G. P.—"Korean Lespedeza; A New Forage Crop." *U. S. Dept. Agr. Dept. Circ. 317.* 1924.

BURR CLOVERS

754. Adaptation and Description. Uses. Most of the burr clovers are annuals, being native to the countries about the Mediterranean Sea. There are a large number of species; the one which is most commonly used in the southern states is the spotted burr clover (*Medicago arabicca*) and in California the burr clover (*Medicago hispida*).

Burr clover is grown in sections having mild winters and is not winter hardy north of the cotton belt. It grows best in cool, moist weather and constitutes one of the best winter cover and green manure crops. It will grow on land decidedly sour. Burr clover is commonly grown in the United States in California and the Gulf states, including most of the cotton belt. The plant is prostrate in habit with small yellow flowers, borne in clusters of 5 to 10, which produce coiled pods, usually toothed or spiny, giving the name burr clover.

The outstanding use of burr clover is for cover and green manure. It is also extensively used as a pasture crop. It, like lespedeza, may be seeded in Bermuda grass where it will reseed itself. **(197)**

FLORIDA BEGGARWEED

Florida beggarweed (*Desmodium purpureum*) is an annual. In the United States, this legume appears to be adapted to the southern cotton belt states, where it appears to have considerable value for pasture, hay, and soil improvement.

755. Description and Adaptation. The plants of Florida beggarweed range from 3 to 10 feet in height with somewhat woody stalks, which branch and make a slender bush-like growth. The stems are hairy, the leaves large, trifoliate, from 2 to 4 inches in length. The seed are borne in panicles in long, jointed, rough pods. The greatest value of beggarweed is for the improvement of very poor or worn-out soil. It reseeds abundantly and one seeding is all that is necessary as it will volunteer in every cultivated crop after it is laid by. It often volunteers after winter oats and makes a fair crop of hay or good fall pasture. Ten pounds of seed per acre will make a hay crop and 5 pounds a good seed crop when the hulled seed is used. It takes 30 pounds of unhulled seed per acre for a hay crop. Leach[11] advises sowing broadcast on the top of freshly harrowed or cultivated ground.

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[11] Leach, C. F.—"Beggarweed." *Fla. Dept. Agr. Quart. Bul.* Vol. 34, No. 3, Supplement. Apr., 1924.

No covering is necessary but if the land is rolled after seeding germination will be quicker.

DALEA

756. Description and Adaptation. Dalea (*Dalea alopecuroides*) is an annual legume, sometimes referred to as Woods clover, which has been used as a green manure in western Iowa. On land seeded to wheat annually large yields have been secured between summer harvest and fall seeding. The plant is not palatable either as hay or as pasture. Dalea is an upright annual with pinnate leaves having 15 to 40 leaflets. It carries small pinkish white flowers on a spike 1 to 2 inches long, and makes a growth of from 2 to 3½ feet. It produces seed abundantly, having given yields as high as 10 bushels of cleaned seed per acre after a winter wheat crop. It appears to have a somewhat narrower range of soil adaptation than many of the clovers. It has done well on strongly acid soil and appears to be better suited to sandy soils than to the more fertile black loams. When plowed under the seed will carry over for several years in the soil, the crop volunteering after a crop of small grain. It is not known ever to have proven troublesome in a cultivated crop. **(197) (187)**

VETCHES

The vetches are native of the Mediterranean region and are rather extensively found in Europe. There are several varieties, of which the two most important ones are common (*Vicia sativa*) and hairy or winter vetch (*Vicia villosa*). Two others, the purple and the Hungarian vetch, are also well known. These vetches are either annuals or winter annuals, though the hairy, or winter vetch, sometimes behaves as a biennial.

757. Description and Adaptation. Vetch produces a single stem in thick stands or many stems when grown alone. The stems are vining, branching, decumbent and equipped with tendrils on the ends of the branches which enable them to be somewhat ascending when support is available. The leaves are pinnate with seven to many pairs of leaflets. The flowers, which are blue violet, purple, and very rarely white in color, are borne in pairs on short to long seed stalks.

Hairy vetch acts as a biennial if planted in the spring of the year. Hungarian vetch is a white-flowered variety of hairy vetch. Purple vetch resembles hairy vetch in many respects; however, it is smooth, and is not so hardy as common vetch. **(197)**

Vetches are adapted to well-drained soil, doing well on loam and sandy loam and are used for soil improvement on very sandy or gravelly soils. The common vetch is adapted only to the warmer sections of the cotton belt and to the coastal regions of Washington, Oregon, and California, having mild winter temperatures. As a spring sown crop common vetch does well where the summers are fairly cool. It is injured very materially by hot, humid weather. Hairy vetch succeeds well wherever common vetch does, but it can be grown much farther northward, withstanding the winters as far north as Michigan, New York, and the New England states. Hairy vetch succeeds especially well on sandy soil and can be grown successfully on any well-drained soil. It is very drouth resistant and will often make a good crop when common vetch fails.

758. Uses and Culture of the Crop. Vetch is used for hay, soiling, pasture, silage, as a green manure, and as a cover crop.

The common vetch is grown extensively in Oregon and Washington. Schoth and Hyslop,[12] of the Oregon Station, report in that state early planting in the fall,—late September to the middle of October,—is best. It may be planted earlier for green manure and as a cover crop. If spring planted it must be put in very early to make a good growth. They state that 60 to 80 pounds of seed per acre are required when seeded alone and 40 pounds when in mixture with small grains. Mixtures of grain and vetch are preferred for hay, and sometimes for seed. Rye and vetch is a good soiling, cover, and green manure mixture. If allowed to mature the seed can be separated fairly well. Oats and vetch are used generally and the separation of seed is fairly easy. Barley and vetch, and wheat and vetch, are used for silage and for hay, but should not be sown together for seed. Under Oregon conditions vetch is reported to be one of the best silage crops, considering the food value and the cost of production. It is a good green feed crop for spring and early summer use and is one of the best green manure and cover crops.

Piper and McKee [13] state that hairy vetch can be grown in almost every part of the United States and that when seed is reasonable in price it is the best winter legume for all localities in the eastern half of the United States, where red clover fails or where crimson clover is not a success. In the northern states it can be used to seed in corn at the last cultivation and the following spring furnish a crop for green manure or hay. They suggest that vetch should not as a rule be sown in rotation with wheat as the vetch tends to volunteer and the seed is very difficult to separate from the wheat.

759. Harvesting for Seed. Megee [14] states that most of the seed of hairy vetch produced in the United States is grown in Michigan.

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[12] Schoth, H. A., and Hyslop, G. R.—"Common Vetch." *Ore. Agr. Expt. Sta. Bul. 213*. 1925.

[13] Piper, C. V., and McKee, Roland—"Vetches." *U. S. Dept. Agr. Farmers' Bul. 515*. Revised Edition. 1917.

[14] Megee, C. R.—"Hairy Vetch." *Mich. Agr. Expt. Sta. Circ. 50*. 1922.

Due to the fact that the growth is indeterminate and all seed do not ripen at the same time the buds on the lower branches of the vetch develop first, shattering before the seed on the upper branches have turned black. Vetch seeded with rye is cut best when approximately three-fourths of the pods are ripe. The loss from shattering of the vetch will not be heavy, but many of the seeds will be immature. If all of the pods are allowed to ripen, the loss from shattering will be heavy, but the seed will be of better quality. If harvested when wet with dew the percentage of shattering will be reduced.

STUDY QUESTIONS ON CHAPTER XXVIII

1. What characteristics have made red clover so widely advocated as a rotation crop?
2. Why is red clover not grown more extensively as a rotation crop?
3. Is the acreage of red clover increasing or decreasing?
4. What factors influence the extent to which red clover is harvested for seed?
5. Give instructions for seeding red clover.
6. At what stage of maturity can red clover best be harvested for hay? For seed?
7. In what way, if any, is alsike superior to red clover? Red clover superior to alsike?
8. Describe crimson clover in such a way that it could be identified in a seeding of the common clovers.
9. What is the range of adaptation of crimson clover?
10. How is crimson clover used in the rotation?
11. Describe the white Dutch clover so that one could identify it.
12. Outline the uses and adaptation of white Dutch clover.
13. Describe Japan clover so that one could identify it.
14. Outline the adaptation and uses of Japan clover.
15. Describe and outline the uses and adaptation of burr clover.
16. Describe the different vetches together with their adaptation and use.

APPLICATION ASSIGNMENTS ON CHAPTER XXVIII

1. You have been using red clover in the past in your rotation but have failed repeatedly to secure satisfactory stands. You wish to make sure of a stand this year. What precautions will you take?
2. Your soil is too acid to make red clover a sure crop and you are not able to lime at present. You wish a clover which you can seed in a small grain nurse crop on this soil and which is well suited for hay. What clover will you use? Explain.
3. Alsike seed can be had at $19.00 per bushel while red clover seed will cost $23.00. What other considerations will determine the crop that you will use? Explain.

4. You have been asked to speak at a local meeting of farmers on "Clovers Suitable for Our Locality." You are expected to give information on soil requirements, methods and rates of seeding, value for hay, pasture and green manure and yields which may be expected. Prepare an informational outline of the subject matter which you will present.

CHAPTER XXIX

SOYBEANS

The soybean (*Soja max*) is a native of eastern Asia, and was introduced into this country in about 1800. It is only during the last 10 or 15 years that it has become a crop of much importance in the United States. At the present time the soybean is cultivated abundantly in China, Korea, Manchuria, Japan, and the United States.

760. Description of the Plant. The soybean plant is an annual, bushy to viny, growing from 2 to 5 or 6 feet in height, depending upon the fertility of the soil, the length of the growing season and the variety. The flowers of the soybean plant are small, white or purple in color, and borne on short axillary racemes which usually carry 15 flowers in a cluster.

The soybean flower is normally self-pollinated, but Garber and Odland[1] state that a limited amount of natural crossing occurs. With a particular set of conditions they found that the extent of natural crossing which produced varietal contamination was 0.14 per cent in 1922 and 0.36 per cent in 1923. At maturity the seed are borne in pods which are compressed somewhat, each bearing 2 to 4 seed and varying in length from 1 to 3 inches. The pods are gray or vary from gray to black in color and are pubescent. The seed are elliptical in outline, may be somewhat flattened, and vary widely in size of seed and color. The color varies from a light yellow through olive green to black, and in a few varieties the seed coat is of two or more colors. The cotyledons are either green or yellow. The leaves and stems of the common varieties of soybeans are hairy, although plants with smooth stems have been found. The pubescence is either gray or tawny. The leaves are ovate, in some varieties narrow. They vary in size, each individual leaflet commonly being better than 2 inches in length. At maturity the leaves commonly turn yellow and fall from the plant, though a few varieties retain their leaves when the plant is fully mature.

761. Soil Adaptation. Soybeans make a satisfactory growth on a very wide range of soil types. When inoculated, they make a good growth on poor soil, but in the region to which cowpeas are adapted the cowpea is perhaps better for this purpose. They grow well in both dry and moist sections, but will not grow where water stands for any considerable length of time. Lime will increase the yields of the soybean, although they will grow well on soil so acid that most of the legume crops cannot be successfully grown.

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[1] Garber, R. J., and Odland, T. E.—"Natural Crossing in Soybeans." *Jour. Amer. Soc. Agron.* Vol. 18, No. 11, p. 970. Nov., 1926.

762. Climatic Adaptation. Such a range of soybean varieties is available that it is possible to grow the soybean in practically all sections of the United States where rainfall will permit. Early maturing varieties are grown in the North and late maturing varieties in the South. In the extreme southern portion of the country, certain varieties have a tendency to make top growth but produce no seed. The leaves of the soybean plant in general will stand considerable frost both when young and when approaching maturity.

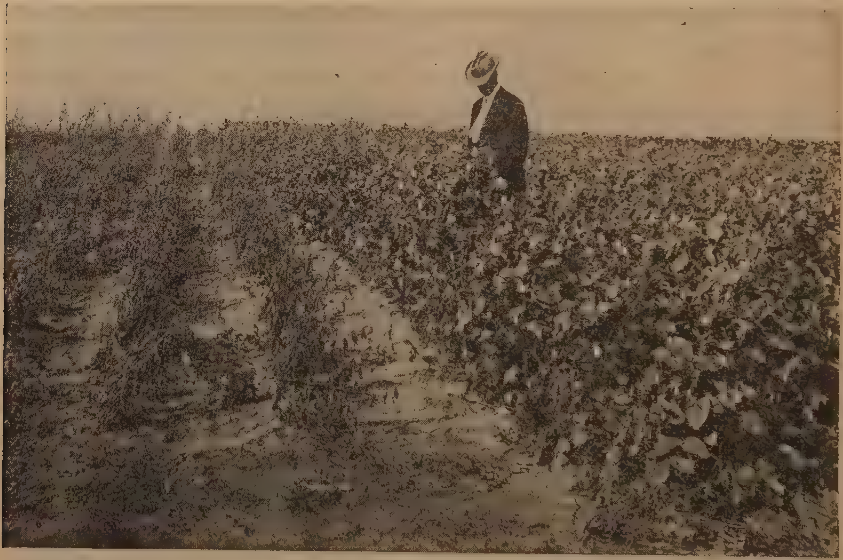

Fig. 138.—An early and a late maturing variety of soybeans at the Iowa Station. The soybean plant drops its leaves as maturity approaches. *Keeping in mind a particular farm and a particular locality, determine upon (a) the varieties best suited for hay production; (b) for seed production; (c) for planting in corn for hogging down and (d) for planting in corn for silage.*

763. Soybean Varieties. A very large number of different varieties of soybeans are available. In the selection of a variety the yield of forage or seed is probably the most important consideration. The purity of the crop, color and size of seed, resistance to disease, and shattering, quality of the hay made, the coarseness of the plant and its ability to retain the leaves are all factors which are considered in the selection of a variety.

Morse[2] gives a description of the outstanding varieties in *U. S. Dept. of Agr. Farmers' Bulletin 1520,* and this reference may be used to advantage when considering the growing of this crop. Varieties are available and which are suited to planting as far north as central Minnesota and which will mature in 90 days, while other varieties, best suited to planting in the Gulf States, require as much as 160 to 175 days to mature. Reports from local stations should be used in determining varieties best suited to a particular location.

764. Uses of the Crop. Morse[3] gives the following diagrammatic outline of the various uses of the soybean plant and seed.

- Green manure
- Forage
  - Hay
  - Ensilage
  - Soiling
- Pasture
- Meal
  - Human food
    - Breakfast foods
    - Diabetic foods
    - Flour
      - Bread
      - Cakes
      - Muffins
      - Biscuit
    - Infant foods
    - Macaroni
    - Crackers
    - Milk
  - Stock feed
  - Fertilizer
- Oil
  - Glycerin
  - Explosives
  - Enamels
  - Varnish
  - Food products
    - Butter substitutes
    - Lard substitutes
    - Edible oils
    - Salad oils
  - Waterproof goods
  - Linoleum
  - Paints
  - Soap stock
    - Soft soaps
    - Hard soaps
  - Celluloid
  - Rubber substitute
  - Printing inks
  - Lighting
  - Lubricating
- Dried beans
  - Soy sauce
  - Boiled beans
  - Baked beans
  - Soups
  - Coffee substitute
  - Roasted beans
  - Vegetable milk
    - Cheese
      - Fresh
      - Dried
      - Smoked
      - Fermented
    - Condensed milk
    - Fresh milk
    - Confections
    - Casein
  - Breakfast foods
- Green beans
  - Green vegetables
  - Canned
  - Salads

In China, Japan, Manchuria, and in other regions of Asia where it is extensively grown, the soybean is used primarily for human food and for the manufacture of oil and food products. In this country the soybean has been grown largely for seed, although its use as a forage crop is increasing rapidly. Soybeans may be used for green manuring purposes, as a soiling crop, or as a combination or supplementary crop to be grown with crops such as corn and sorghum for silage, for hogging down, or for pasturing.

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[2] Morse, W. J.—"Soybeans: Culture and Varieties." *U. S. Dept. Agr. Farmers' Bul. 1520.* 1927.

[3] Morse, W. J.—"The Soybean: Its Culture and Uses." *U. S. Dept. Agr. Farmers' Bul. 973.* 1918.

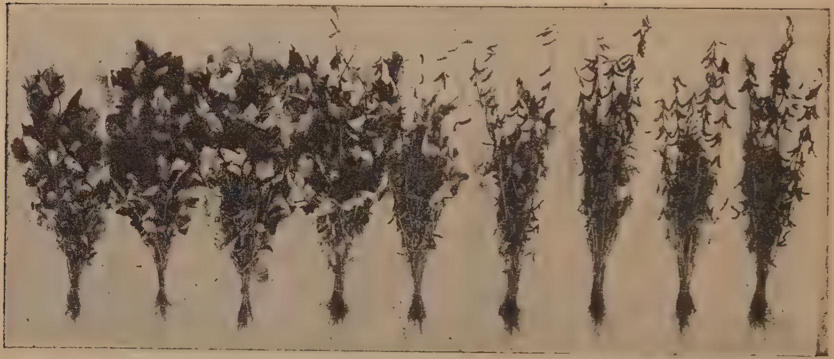

FIG. 139.—Representative bundles of soybeans harvested in September from plots planted at weekly intervals at the Iowa Station, beginning April 25. *Considering a given locality, through how long a period is it practically possible to plant soybeans for seed production? For the production of a hay crop?*

765. Culture of the Crop. Soybeans have been seeded broadcast, drilled solid, and in rows of varying distances apart. Experimental evidence as to the method of planting for seed is available from a number of stations.

765a. Method of planting soybeans for seed. Summary.

STATION	YEARS	BROADCAST	DRILL	IN ROWS				
				16″	24″	30″	36″	42″
Iowa Bul. 228	7	20.75	25.43	24.27		23.14		
Ind. Bul. 238	16	10.6	19.2		19.2	18.7	15.9	15.5
Ill. Bul. 198	1	26.5	25.4	26.5	25.9	25.4	23.8	19.9
Ohio Bul. 312	6		19.68			22.05		
Del. Bul. 96	4		26.3			20.4		

Similar data have been obtained as to the effect of method of seeding on the forage yields.

765b. Yields of soybean hay, tons per acre, from various methods of seeding.

STATION	YEARS	BROADCAST	DRILLED	IN ROWS					
				16″	18″	24″	30″	36″	42″
Iowa Bul. 228	4	2.75	2.99	2.97			2.52[a]		
Ind. Bul. 238	16	1.68	3.0			2.24	2.16	2.04	1.63
Ohio Bul. 312	6		2.0				1.71		

[a] Under comparable conditions drilled beans produced 2.80 tons.

A considerable number of stations have compared the results secured from different rates of seeding. The influence of the rate of seeding on the yield as reported from different states is shown in Tables *765c*, *765e*, and *765f*.

765c. Rate of seeding soybeans as influencing the yield of threshed beans; bushels per acre. Summary.

STATION	YEARS	METHOD OF SEEDING	VARIETY	RATE OF SEEDING—POUNDS PER ACRE				
				40	60	80	90	120
Iowa Bul. 228	6	Drilled 8″ rows	Manchu		22.66		24.59	25.67
Iowa Bul. 228	6	Drilled 16″ rows	Manchu		21.72		24.16	24.52
Iowa Bul. 228	6	Broadcast	Manchu		17.42		19.87	22.86
Ind. Bul 238	16	Drilled solid	Early Brown and Ito San	19.2	19.7	18.2		

The time of seeding soybeans has been tested at a number of stations both for seed and for forage.

765d. Date of seeding soybeans as influencing the yield of seed and hay. Summary.

YEARS	STATION	RANGE OF SEEDING DATES	YIELD 1ST SEEDING		YIELD LAST SEEDING		BEST SEEDING			
							SEED		HAY	
			Seed	Hay	Seed	Hay	Date	Yield	Date	Yield
6	*Iowa Bul. 228*	4/19 to 7/5	21.89	2.63	8.41	1.28	5/24	23.49	5/10	2.69
2	*Va. Bul. 235*	5/11 to 7/14	30.73	4.88	Frosted	1.41	5/11	30.73	5/11	4.88
1	*U.S.D.A. Farmers' Bul. 973*	5/1 to 8/1	33.3	2.09	Not mature	0.87	5/15	34.0	5/15	2.39
1	*Ohio Bul. 384*	5/7 to 6/12	24.02	1.07	17.12	1.20	5/19	24.75	6/12	1.20

766. Cultivation of Soybeans. Eradicating weeds from the field in just so far as possible before the soybeans are planted is desirable. In order to check weed growth in soybeans drilled solid or seeded broadcast, various means of cultivation have been tried. When weeds can be controlled there are certain advantages in seeding solid or in broad casting. Cultural tests using various implements to eradicate weeds have been made at a number of stations.

Hughes and Wilkins[4] report the use of different tools for cultivating soybeans when planted solid at the Iowa Station in Table *766a*.

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[4] Hughes, H. D., and Wilkins, F. S.—"Soybeans for Iowa." *Iowa Agr. Expt. Sta. Bul. 228.* 1925.

765e. Rate of seeding soybeans in rows as influencing the yield of threshed beans; bushels per acre. Summary.

YRS.	STATION	METHOD OF SEEDING	VARIETY	RATE OF SEEDING—POUNDS							
				15	20	30	35	40	45	55 to 60	Over 60
1	*Ark. Bul. 211*	3 ft. rows	Laredo	9.65	8.55	8.09	8.30	8.67	7.63	7.58	
1	*Ark. Bul. 211*	3 ft. rows	Mammoth Yellow	7.74	8.48	8.13	7.71	7.29	8.76	7.94	7.23
16	*Ind. Bul. 238*	24-28″ rows	Early Brown and Ito San		18.7	19.2					
16	*Ind. Bul. 238*	42″ rows	" "		15.5	16.5					
6	*Ohio Bul. 312*	28″ rows	Medium Green	20.26		20.31			22.49	22.05	19.68
6	*Iowa Bul. 228*	Aver.	Several			20.65				24.76	24.54

765f. Rate of seeding soybeans as influencing the yield of hay; tons per acre. Summary.

YRS.	STATION	METHOD OF SEEDING	VARIETY	RATE OF SEEDING—POUNDS							
				15	20	30	40	60	90	120	150
4	*Iowa Bul. 228*	Drilled 8″ rows	Manchu					2.71	2.74	2.75	
16	*Ind. Bul. 238*	Drilled 8″ rows	Early Brown and Ito San				2.54	2.63	3.02		
6	*Ohio Bul. 312*	28″ rows	Medium Green	1.62		1.63	1.77	1.70			
2	*Va. Bul. 235*	Broadcast	Wilson					1.91	2.26	2.23	
2	*Va. Bul. 235*	32″ rows	Wilson	3.39	3.87	4.09					
	Wis. Bul. 359		Wilson					2.70	2.37	2.45	2.32

766a. Cultivation of soybeans. Iowa.

Implement Used	Comparative Stand of Plants End of Season	Yields of Seed		Yields of Hay Weed Free	Per Cent of Weeds in Hay
		7-Yr. Av.	3-Yr. Av.		
None	100	20.71	21.13	1.88	27.8
Harrow	71.4	23.35	24.90	2.13	12.1
Weeder	71.4	25.62	26.29	2.11	11.9
Rotary hoe	84.4		24.55	1.94	16.9

They report the results secured from cultivating across the rows and lengthwise of the rows with each of the above implements and conclude that the direction of cultivation has but little effect on the stand or the yield of seed or hay. When the beans were seeded broadcast, cultivation reduced the stand to a greater extent than when drilled solid. The authors believe that the rotary hoe was not moved over the field fast enough in these trials to secure as satisfactory results as would otherwise have been possible.

Beans were cultivated when ½, 3, and 6 inches high at the Iowa station. The stand of soybeans was reduced more and the weeds killed better at the ½ inch, next at the 3-inch and last at the 6-inch height of the soybeans. Plots cultivated in the afternoon showed a somewhat better stand than those cultivated in the morning. The results of the Iowa studies indicated that it was best to give the first cultivation when the beans are ½ inch in height, again when 3 inches, and a third time when about 6 inches high.

Wolfe[5] reports that beans seeded broadcast with no cultivation produced 2.90 tons of hay per acre, while similar seedings harrowed when the plants were coming through the ground produced 3.68 tons and those harrowed when 3 inches tall 3.28 tons. Beans planted in rows with no cultivation produced 2.35 tons; 1 cultivation, 3.50 tons; 2 cultivations, 3.50 tons, and 3 cultivations, 4.18 tons of hay per acre.

767. Soybeans in Mixtures with Other Crops. The Iowa Station[6] recommends that when soybeans are seeded broadcast or drilled solid on ground inclined to be weedy or with so much trash on the surface that it cannot be cultivated that 6 to 8 pounds of Sudan grass per acre be seeded with the beans. The Sudan takes the place of foxtail and other weeds which would otherwise appear and gives a very good yield of excellent hay. Soybeans are also grown in mixture with other sorghums as well as with corn.

Some degree of success is reported from the Iowa Station in *Bulletin*

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[5] Wolfe, T. K.—"Soybean Culture." *Va. Agr. Expt. Sta. Bul. 235.* 1924.

[6] Hughes, H. D., and Wilkins, F. S.—"Soybeans for Iowa." *Iowa Agr. Expt. Sta. Bul. 228.* 1925.

228 for soybeans seeded in oats in the spring, the beans making a growth of forage following the harvest of the small grain.

768. Rotation Value of Soybeans. Metzger *et al.*[7] report as a four-year average that wheat after soybeans averaged 3.14 bushels higher than after corn in one field, 3.85 bushels higher in a second field, and 1.83 higher in a third field. They state that a number of growers have reported decreased yields after soybeans harvested for seed, while experiments at four different locations of the state have suggested the opposite results.

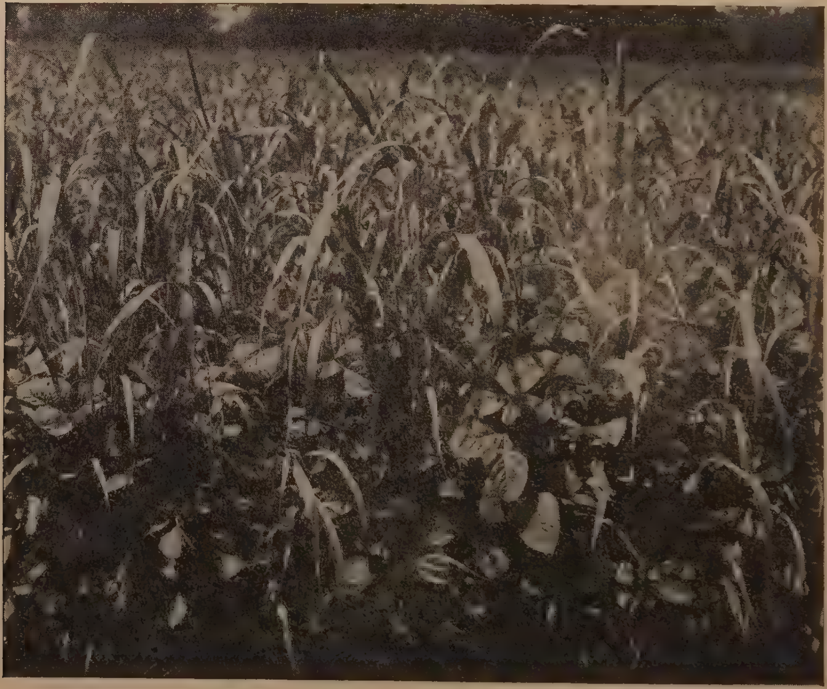

Fig. 140.—A growth of soybeans and Sudan grass secured by seeding a bushel and a half of beans and eight pounds of Sudan grass. *Compare the acre value of soybeans, Sudan grass, and a soybean-Sudan grass mixture for hay, having in mind palatability, nutritive value and yield per acre. Under what conditions is it advisable to seed Sudan grass in soybeans?*

Williams and Park [8] report the comparison of wheat yields following corn, soybeans, potatoes, and oats. The yield of wheat was 28.21, 38.51, 38.15, and 37.24, respectively. (197) (187)

McClelland [9] reports an increase in yield of corn of better than

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[7] Metzger, J. E., *et al.*—"Soybeans." *Md. Agr. Expt. Sta. Bul. 277.* 1925.

[8] Williams, C. G., and Park, J. B.—"Soybeans: Their Culture and Use." *Ohio Agr. Expt. Sta. Bul. 312.* 1917.

[9] McClelland, C. K.—"Variety and Rotation Experiments with Soybeans." *Ark. Agr. Expt. Sta. Bul. 199.* 1925.

45 per cent following soybeans as compared to the yield following oats. Soybean stubble was less valuable than cowpea stubble, but there was no difference when full crops were turned under.

Wolfe[10] reports a comparison of the yield of wheat after soybeans handled in various ways. Where the soybeans were cut for hay, the yield of wheat was 26.2 bushels; where they were turned under at the hay stage, the yield of wheat was 29.2 bushels; where no soybeans were used, the yield of wheat was 19.1 bushels.

The Iowa Station has reported in *Iowa Bulletin 228* the average yield of 8 crops of corn following soybeans in as many years, comparing the yields with those secured following oats and following Sudan grass. Corn is grown in a 2-year rotation in each case. The oats, Sudan grass, and soybeans were removed from the land, cornstalks being the only organic matter turned under during the 8-year period. The land was fall-plowed in each case in preparation for corn. The average yield of corn following each of the 3 crops was almost identical.

769. Harvesting Soybeans for Seed. Soybean plants are inclined to shed their leaves at maturity. There are a few varieties that do not, but those generally grown for seed purposes have shed all their leaves by the time the beans are fully mature and ready for harvest.

Soybeans are commonly harvested for seed with the grain binder, cured in the shock, and threshed either with a bean huller or with an ordinary thresher with concave teeth removed and the speed of the cylinder reduced to about 600 revolutions per minute. The beans may be cut with a self-rake reaper or a mower with a swathing device. When harvested in this way the crop is cured in windrows or in small cocks. This method is not so satisfactory as harvesting with a binder as there is more loss from shattering.

Recently combines have been used for harvesting and threshing soybeans with very satisfactory results.

Machines which will harvest the beans from the mature standing plant are used extensively in the South Atlantic states. Various types of such machines are available.

770. Soybean Hay. Soybean varieties selected for hay purposes usually are the relatively late maturing sorts for the section. The slender vining or twining types seem better adapted for this purpose than the more bushy types. **(684)**

Willard[11] states that the weight of leaves increases until the beans are well formed and remains nearly constant for about three weeks and then decreases rapidly. The percentage of leaves in the hay decreases steadily from blooming time until full maturity. Sixty per cent of soybean hay is leaves when the beans are well formed and about 50 per cent when the pods are about one-half filled. Soybeans are best cut for hay between the time when the beans are well formed and the pods half filled.

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[10] Wolfe, T. K.—"Soybean Culture." *Va. Agr. Expt. Sta. Bul. 235.* 1924.

[11] Willard, C. J.—"The Time of Harvesting Soybeans for Hay and for Seed." *Jour. Amer. Soc. Agron.* Vol. 17, No. 3, p. 168. Mar., 1925.

In Iowa an increasing number of growers are reported as allowing the crop to become somewhat more mature and then cutting with the binder, shocking in six bundle shocks, set long ways north and south, with the butts of the bundles well apart.

FIG. 141.—A good crop of soybeans grown for hay at the Iowa Station. *What soil conditions are necessary for a satisfactory growth of soybeans? What yield per acre can be expected? How does soybean hay compare with alfalfa hay in feeding value?*

Grantham [12] presents an analysis of the soybean plant at various stages of maturity in Table *770a* on page 625.

771. Soybeans in Corn for Silage. Numerous tests at various stations in the United States have compared the yield of silage from corn and soybeans seeded at various rates in comparison with the yield from corn alone.

[12] Grantham, Arthur E.—"Soybeans." *Del. Agr. Expt. Sta. Bul. 96*. 1912.

770a. Composition of air-dry samples of soybeans cut at different stages of maturity.

MATURITY OF PLANT	MOISTURE	ASH	PROTEIN	NITROGEN-FREE EXTRACT	CRUDE FIBER	FAT
In blossom	5.85	7.36	12.50	43.92	28.77	1.60
Pods forming	5.96	8.28	17.06	36.75	30.27	1.68
Seed half developed..........	6.17	5.36	11.50	41.98	31.71	3.28
Seed nearly full size, leaves green	6.14	5.93	11.37	42.90	28.96	4.80
Seed full size, leaves yellow...	6.67	7.03	7.44	42.50	31.52	4.84

Slate and Brown [13] report a 4-year test in which the combination of corn and soybeans produced 500 pounds of dry matter per acre over that of corn alone, comparing the average of 27 corn and 72 corn and soybean plots. As harvested, the corn and soybean silage averaged 1.82 per cent protein and contained 672 pounds per acre, while the corn silage averaged 1.54 per cent protein and contained 550 pounds per acre. They state that it would require 300 pounds of 40 per cent cottonseed meal to supply the difference in the yield of protein. In growing the crop they recommend 1 stalk of corn to 3 of beans per 12 inches of row in order to secure the largest total yield per acre of green and of dry matter and of protein. Drilling the corn and soybeans was more advantageous than planting both in the same hill or planting the beans between the hills of corn. They state that approximately $10.00 per acre will be added to the value of the silage by planting soybeans with corn when the soybeans are planted at the same operation with the corn on land that is not weedy and can be cultivated only one way and where the binder can be used for harvesting.

Data from Indiana, Ohio, Iowa, Missouri, and Connecticut indicate that drilling is the best method of planting the corn and soybeans when grown for silage purposes, if due precautions are taken to plant the crop on relatively clean ground. (456)

The best ratio of corn to soybeans in order to secure the largest yield of silage was found to be different at almost each experiment station, due, probably, to variations in soil moisture, rainfall, fertility, the variety of corn grown, the method of planting, and other factors.

Etheridge and Helm [14] state that soybeans planted with corn at the time of planting corn may be expected invariably to reduce the yield of corn, the reduction varying with the ratio of beans to corn in the mixture. With 3 bean plants per 3-stalk hill of corn on upland soil, the total five-year average loss of corn was fully equal to an average annual crop upon the same land,—about 40 bushels. When the mixture was drilled at the rate of 2-stalks of beans and 2-stalks of corn per check rowed hill, the total loss for a three-year period was only 12 bushels per acre. (455) (456)

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[13] Slate, W. L., Jr., and Brown, B. A.—"Corn and Soybeans as a Combination Crop for Silage." *Conn. [Storrs] Agr. Expt. Sta. Bul. 133.* 1925.

[14] Etheridge, W. C., and Helm, C. A.—"Corn and Soybeans." *Mo. Agr. Expt. Sta. Bul. 220.* 1924.

FIG. 142.—Soybeans planted in corn for silage. *Under what conditions is this practice profitable? Explain.*

772. Feeding Value of Soybeans. Soybean seed is high in protein and oil. It has been tried in a number of tests as a protein supplement in feeding animals.

Hogs—Hog Off. Weaver[15] states that hogs harvesting corn and soybeans produced more pork per acre, made more rapid gains, and required less feed per 100 pounds of gain than did hogs harvesting corn alone. When tankage was added to the ration, indications were that soybeans planted with corn and hogged off would not entirely take the place of tankage.

Godbey and Durant[16] report that pigs on mature soybeans and corn made faster gains than those in a dry-lot on corn and tankage. They required less feed to produce 100 pounds of pork and produced more economical gains than the dry-lot method of feeding hogs.

Lambs—Hay. Kammlade and Mackey[17] found that soybean hay, although not fully equal to alfalfa, could be used in the place of alfalfa hay in the ration for fattening lambs. They state that the edible portion of the soybean hay was as palatable as alfalfa hay and as efficient in producing gains, but that there was a much larger amount of refuse in soybean hay.

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[15] Weaver, L. A.—"Hogging Down Corn and Soybeans." *Mo. Agr. Expt. Sta. Bul. 224.* 1924.

[16] Godbey, E. G., and Durant, A. L.—"Soybean Forage for Hogs." *S. C. Agr. Expt. Sta. Bul. 228.* 1926.

[17] Kammlade, W. G., and Mackey, A. K.—"The Soybean Crop for Fattening Western Lambs." *Ill. Agr. Expt. Sta. Bul. 260.* 1925.

Dairy—Beans. McCandlish, Weaver, and Lunde[18] report that cracked soybeans appear to be worth $60.00 per ton for the feeding of milk cows when old process linseed oil meal was worth $45.00 per ton.

Fairchild and Wilbur[19] state that soybean oil meal and linseed oil meal were of practically equal value for milk and fat production in the dairy ration. They also found that ground soybeans gave better results than either soybean oil meal or linseed oil meal. They conclude from these trials that ground soybeans are one of the best protein supplements which can be used in the dairy ration in Indiana.

Dairy—Hay. Olson[20] reports that soybean hay is slightly more efficient for both milk production and for fat production than alfalfa hay; also that when oil meal is selling for $60.00 per ton, ground soybeans are worth $72.00 per ton for dairy cows. Ground soybeans did not noticeably affect the consistency of the butter until the grain ration contained 50 per cent or more of ground soybeans.

Bechdel[21] states that in feeding tests at the Pennsylvania station soybean hay and alfalfa hay of good quality are of equal value for milk and butterfat production.

Schaefer[22] reports that soybean hay proved more palatable than timothy hay and resulted in a saving of 46 per cent in concentrates when fed instead of timothy; likewise in a saving of 93.6 per cent in the expenditure for mill feed.

STUDY QUESTIONS ON CHAPTER XXIX

1. How do you account for the fact that in the United States only in comparatively recent years has there been any considerable acreage planted to soybeans?
2. What other plant does the soybean most resemble and what are the distinguishing characteristics?
3. Can different soybean varieties be grown on adjoining plots without mixing?

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[18] McCandlish, A. C., *et al.*—"Soybeans as a Home Grown Supplement for Dairy Cows." *Iowa Agr. Expt. Sta. Bul. 204.* 1922.

[19] Fairchild, L. H., and Wilbur, J. W.—"Soybean Oil Meal and Ground Soybeans as Protein Supplements in the Dairy Ration." *Ind. Agr. Expt. Sta. Bul. 289.* 1924.

[20] Olson, Thomas M.—"Soybeans for Dairy Cows." *S. Dak. Agr. Expt. Sta. Bul. 215.* 1925.

[21] Bechdel, S. I.—"Soybean Hay for Milk Production." *Pa. Agr. Expt. Sta. Bul. 201.* 1926.

[22] Schaefer, O. G.—"Soybeans and Soybean Hay in the Dairy Ration." *Minn. Agr. Expt. Sta. Bul. 239.* 1927.

4. What are the climatic and soil limitations of the soybean crop?
5. In general, what types of soybeans are grown in the North? In the South? List four varieties adapted to the central corn belt. To the cotton belt.
6. What crops compete with feed and food products made from the soybean seed.
7. When planted in rows, with what other crop are soybeans most likely to compete for labor? Suggest ways in which the crop can be handled so as to avoid or greatly reduce such competition.
8. Give specific directions to a beginner, telling him how to grow a crop of beans and harvest for seed.
9. What changes would you make if the crop were to be grown for hay?
10. The soybean is a legume. What effect does this crop have on the fertility of the soil when included in a rotation and the crop harvested as hay?
11. What is the effect of growing corn and soybeans together on the yield of corn grain? On the yield of forage? On the acre feeding value?
12. What concentrates are similar to ground soybeans in feed value? Compare these feeds.

APPLICATION ASSIGNMENTS ON CHAPTER XXIX

1. You are operating a farm which is exceedingly variable as to fertility and acidity of the soil and in drainage. You plan to seed 20 acres of soybeans. To what soil conditions will you be limited? Describe the soils on which this crop cannot be grown successfully.
2. You wish to grow 20 acres of soybeans but do not want to decrease the acreage of corn. How will you seed and handle the soybean crop?
3. You have your choice of seeding soybeans on heavily manured corn stubble by plowing or disking, or on land in wheat the past year and which was fall-plowed. Where will you seed? Why?
4. You drilled your beans solid with a wheat drill but when they are coming through the ground you discover that many weeds are starting also. What will you do? Explain.
5. You are not able to grow the clovers recommended for green manure. You plan to grow a considerable acreage of soybeans in your rotations and wish to make the crop as valuable in building up the soil as possible. How will you handle them and what precautions will you observe?

CHAPTER XXX

COWPEAS AND OTHER LARGE SEEDED LEGUMES

Cowpeas

Cowpeas (*Vigna sinensis*) may be divided into three general groups, the Catjang or Hindu cowpea, which has small erect pods and small cylindrical seed; the Asparagus or Yard Long Bean, with kidney-shaped seed; and the more commonly known cowpea with slightly curved, rather long, firm walled pods, and rather large seed, somewhat irregular in outline.

773. Description. The cowpea is an annual legume, native of Asia, introduced into general use in the southern states. In appearance it is more like a bean than a pea, having large, broad leaves and long, slender pods. The plant varies in habit of growth from an upright, bushlike plant a foot or more in height with tendrils a few inches in length to a mass of low trailing vines many feet in length. The form of the cowpea plant varies not only with the variety but with the length of season, soil, moisture, and cultural conditions. The blossoms vary in color from white to purple and the pods while usually a light, straw color, in some varieties are brown, purple, or light black. The pods vary in length from 5 inches to approximately 15 inches.

The size of the seed also varies rather widely. In many varieties the seed completely fill the space in the pod so that they are crowded together and flattened at the ends. In general, the seed is kidney or bean shaped except when crowded in this way. The color ranges from white to black with many mottled and mixed colors.

The growth of the plant is not determinate; that is, it usually continues to flower and produce seed until checked by frost. The cowpea leaf is compound, having three parts, with each leaflet varying somewhat in shape, being 2 inches or more in length and remaining green after many of the pods are ripe and dry. The plant has a well-developed tap-root and a large number of branch roots.

774. Adaptation of the Cowpea. The cowpea is a strictly warm weather crop. Its culture in the United States extends from the central part of the corn belt southward. It stands dry weather fairly well but the yield of hay and seed is limited under dry conditions. A very light frost tends to kill the green plants in the fall. The cowpea has been successfully grown on practically all types of soil, but it is of particular value on sandy or poor, thin soils (Figure 29).

775. Uses of the Cowpea. The cowpea may be grown either for hay, ensilage, soiling, pasture, soil improvement, or for seed. Certain varieties, particularly the Blackeye and other white varieties, are commonly grown for human food in the southern states. These uses are discussed separately.

776. Varieties of the Cowpea. Morse[1] states that about 15 varieties of cowpeas are in common cultivation, while there are perhaps 3 times as many more which are grown in a small way. He states that the most valuable American varieties of cowpeas for forage are the Whippoorwill, Iron, New Era, and their hybrids, the Brabham and the Groit.

Morse[2] reports yields of seed obtained at a large number of stations with different varieties as shown in Table *776a* on page 631.

Morse also reports the yields of hay from different varieties at various experiment stations in the country in Table *776b*.

777. Method of Seeding Cowpeas. Several stations report the results secured from seeding cowpeas in different ways. Some of these are summarized in Table *777a* on page 633.

Morse[3] suggests that the best method for the production of seed is to sow in rows about 3 feet apart with the seed 2 to 3 inches apart in the row. For forage or green manuring the seed is sown broadcast or drilled solid with a grain drill. Other investigators agree with Morse in the recommendation with reference to drilling and growing in rows for forage and seed production.

778. Time of Seeding. Several stations have seeded cowpeas at regular intervals through a considerable period. The yields which were secured at a number of the stations have been summarized in Table *778a*, on page 633.

779. The Rate of Seeding Cowpeas. Wiancko *et al.*[4] report drilling cowpeas solid at the rates of 40, 60, and 90 pounds per acre. The yields of seed as a 2-year average were 5.2, 2.5, and 4.4 bushels per acre, respectively. The yields of hay as a 3-year average were 1.4, 2.6, and 2.6 tons per acre, respectively.

Morse[5] states that when cowpeas are sown in corn at the time of the last cultivation they are usually seeded broadcast at the rate of

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[1] Morse, W. J.—"Cowpeas—Culture and Varieties." *U. S. Dept. Agr. Farmers' Bul. 1148*. Rev. ed. 1924.

[2] Morse, W. J.—"Cowpeas: Utilization." *U. S. Dept. Agr. Farmers' Bul. 1153*. 1920.

[3] Morse, W. J.—"Cowpeas: Culture and Varieties." *U. S. Dept. Agr. Farmers' Bul. 1148*. Rev. ed. 1924.

[4] Wiancko, A. T., Fisher, M. L., and Cromer, C. O.—"Soybeans and Cowpeas." *Ind. Agr. Expt. Sta. Bul. 172*. 1914.

[5] Morse, W. J.—"Cowpeas: Culture and Varieties." *U. S. Dept. Agr. Farmers' Bul. 1148*. Rev. ed. 1924.

776a. *Best varieties of cowpeas compared at different agricultural experiment stations. Summary.*

VARIETY	AVERAGE YIELD OF SEED PER ACRE (BUSHELS)														
	Alabama	Arizona	Arkansas	Delaware	Georgia	Indiana	Kansas	Louisiana	Mississippi	Missouri	North Carolina	Oklahoma	South Carolina	Texas	Virginia[a]
Black	21.1	...	15.7	7.4	19.9	8.1	11.1	13.0	14.2	18.6	12.9	...	13.0	20.3	20.0
Brabham	...	...	...	...	11.1	...	...	...	29.1	...	10.0	...	...	4.0	10.6
Clay	10.8	...	9.8	6.6	34.3	5.3	10.9	...	14.0	14.4	13.7	...	13.3	2.1	...
California Blackeye	...	...	...	...	5.9	...	4.1	...	...	...	...	8.1	16.3	...	16.3
Early Buff	...	2.4	...	...	...	...	...	...	...	...	...	...	...	12.6	19.7
Extra Early Blackeye	16.4	...	29.1	5.4	...	14.2	9.9	...	...	...	9.2	...	9.9	7.2	18.8
Groit	...	...	...	8.2	...	...	...	...	26.8	14.8	17.3	2.2	...	8.3	27.3
Iron	14.9	...	...	7.4	15.8	7.2	2.5	5.0	14.8	17.5	8.3	3.3	9.3	14.3	10.9
Large Blackeye	17.0	...	23.6	5.6	31.3	...	12.7	6.0	17.1	14.8	21.7	...	21.7	17.0	26.3
Michigan Favorite	...	...	...	8.2	...	19.3	11.2	...	...	11.4	7.9	...	...	...	19.8
Monetta	...	6.4	...	...	...	...	...	...	...	...	10.9	...	...	1.3	13.2
New Era	22.0	...	39.9	15.6	6.9	14.0	12.4	18.7	22.3	14.0	14.7	5.0	24.2	9.6	25.2
Red Ripper	19.3	...	11.9	...	27.7	...	7.9	4.5	14.2	8.3	14.2	2.0	...	2.7	...
Taylor	23.6	...	19.9	4.9	11.3	...	11.9	...	21.7	...	10.6	2.4	11.5	9.7	18.6
Unknown	14.7	...	2.5	3.5	30.5	...	.5	...	10.0	...	4.4	1.5	...	13.4	...
Whippoorwill	12.4	...	25.6	13.2	25.3	18.3	11.5	12.7	28.5	14.0	14.8	1.0	13.8	16.5	10.1

[a] Arlington Experiment Farm.

776b. *Yields of hay obtained from important varieties of cowpeas at different agricultural experiment stations. Summary.*

VARIETY	AVERAGE YIELDS PER ACRE (TONS)													
	Alabama	Arizona	Arkansas	Florida	Georgia	Indiana	Kansas	Mississippi	Missouri	North Carolina	Oklahoma	South Carolina	Texas	Virginia[a]
Black	1.12	...	2.03	...	0.81	1.76	2.23	2.27	1.74	1.32	1.56	0.81	...	...
Brabham	...	...	...	1.26	1.12	...	...	1.80	...	1.29	2.20	1.12	1.75	1.89
Clay	1.42	0.56	2.88	...	.60	1.93	1.94	2.27	2.11	.97	1.36	...	...	...
Early Buff	...	.77	...	...	...	...	...	...	...	...	...	...	.78	1.48
Early Red	...	1.56	...	...	...	...	...	...	...	1.31	...	...	...	1.54
Extra Early Blackeye	.71	...	1.06	...	...	...	2.17	...	1.56	1.28	...	...	...	.71
Groit	1.23	...	...	.48	...	...	...	2.04	2.08	1.47	1.49	...	1.38	1.90
Iron	1.55	...	...	1.01	1.03	1.97	...	1.98	1.47	1.35	1.66	1.08	.93	1.88
Large Blackeye	...	...	...	...	.98	...	...	1.63	...	1.25	...	.98	...	...
Michigan Favorite	...	...	...	...	...	1.68	2.10	...	1.63	...	...	...	...	...
Monetta	...	2.44	...	...	...	...	...	...	...	1.53	...	...	1.60	1.84
New Era	1.15	...	.65	.53	.45	1.57	2.14	1.77	1.76	1.14	1.11	1.15	...	1.69
Red Ripper	1.86	...	1.73	.66	.93	...	...	2.21	1.88	1.07	1.70	1.86	1.38	...
Taylor	...	.64	1.86	...	.70	...	2.47	2.17	...	1.26	1.74	...	1.10	1.81
Unknown	1.57	...	2.46	1.03	.66	...	...	2.33	...	1.88	2.14	1.55	...	...
Whippoorwill	1.36	...	.91	.92	.86	1.55	2.63	1.92	1.81	1.41	2.15	.86	.69	1.83

[a] Arlington Experiment Farm.

777a. Method of seeding cowpeas as influencing production of hay and of seed; yields in tons and bushels per acre. Summary.

STATION AND PUBLICATION	VARIETY	NO. OF YEARS	METHODS OF SEEDING							
			Seeded Solid		Rows, 18″		Rows, 36″		Rows, 42″	
			Hay	Seed	Hay	Seed	Hay	Seed	Hay	Seed
U. S. Dept. Agr. Farmers' Bul. 1148	Early Buff	3	1.32	10.7	1.32	13.3	...	...	1.18	15.9
	Whippoorwill	3	1.98	4.5	1.90	6.6	...	...	1.84	9.9
	Brabham	3	1.83	3.9	1.90	14.6	...	...	1.66	16.0
Ind. Bul. 172.................	....	4	2.63	4.35	...	...	2.37	3.18	2.20	4.73
Mo. Bul. 123.................	....	1	2.24	....	1.62	...	...	...	1.61	....

778a. Date of seeding cowpeas; yields of hay in tons and seed in bushels per acre. Summary.

STATION AND PUBLICATION	VARIETY	NO. OF YEARS	RANGE OF SEEDING DATES	YIELD FIRST SEEDING		YIELD LAST SEEDING		YIELD BEST SEEDING			
				Hay	Seed	Hay	Seed	Date	Seed	Date	Hay
Arlington, Va.	Groit	3	5/1 —8/1	1.39	28.0	0.41	2.0	6/1	29.0	6/15	1.80
U. S. Dept. Agr. Farmers' Bul. 1148...											
N. C. Bul. 241	Groit	—	5/1 —7/15	0.75	12.8	0.84	13.3	6/1	17.1	7/1	1.25
Kans. Bul. 160	New Era	2	5/12—6/28	1.19	7.16	1.10	4.47	6/9	11.59	6/3	2.26

60 to 90 pounds per acre or with a one-horse wheat drill at the rate of 45 to 60 pounds per acre.

780. Cultivation of Cowpeas. When seeded broadcast, cowpeas ordinarily are not cultivated. When seeded in rows, they are given from 1 to 3 cultivations, similar to either corn or cotton.

781. Cowpeas for Seed. Cowpeas have not been grown extensively for seed, due to the fact that the yield of seed is low and somewhat uncertain and consequently the seed prices are relatively high. Cowpeas ripen so unevenly that normally green and ripe pods occur at the same time until frost. In general, the crop is harvested when approximately three-fourths of the pods are ripe. Hand picking is the most common way of gathering seed. Seed are commonly picked in sacks, dried, and then threshed by hand or by a simple device known as the pod huller. In some cases the vines are pulled up and stacked in small cocks for curing. The mower, the self-rake reaper, the bean harvester, and the combine may all be used when grown in rows, although the habit of growth of the cowpea is not ideal for the use of such machines. The ordinary threshing machine can be used for threshing the seed. Adjustments such as are made in threshing soybeans must be made in order to prevent breaking a considerable portion of the seed.

782. Cowpeas for Hay. When properly cured, cowpeas make an excellent quality of hay. It is, however, somewhat more difficult to cure cowpea hay than soybean hay, due to the succulent vines. The crop is usually cut with the mowing machine when the pods begin to turn yellow and allowed to become well wilted in the swath before raking into small windrows, where it is left for 1 or 2 days, after which the hay is thrown into high and very narrow cocks. Frames are often used on which the vines are hung while going through the curing process though they are not in general use due to the increased cost of labor involved. Cowpea hay is generally recognized as being fully as valuable as red clover hay and almost equal to alfalfa. Cowpea hay has been shown to contain 16.1 per cent of protein; soybeans, 15.9; alfalfa, 15.9; red clover, 13.6, and timothy, 7.

783. Cowpeas for Pasture, Ensilage, and Soiling. Due to difficulties in curing and in harvesting, cowpeas are often harvested by animals. They are very commonly hogged-down, though Good and Smith[6] report that in experiments at the Kentucky Experiment Station it was not found profitable to hog-down cowpeas even though they were supplemented with corn meal when, under the same conditions, it was found highly profitable to hog-down soybeans.

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[6] Good, Edwin S., and Smith, Mark J.—"Hogging Down Soybeans and Cowpeas." *Ky. Agr. Expt. Sta. Bul. 201.* 1916.

When the crop is used as ensilage it is usually ensilage planted in connection with corn or with sorghum. The cowpea crop is regarded as particularly valuable for green feed or for soiling when grown in connection with such crops as corn, sorghum, or millet, due to the protein added by the cowpea plant. However, Karper[7] reports that at Lubbock, Texas, when cowpeas are planted between the rows of grain sorghum there was a loss of the grain crop which was probably greater than the resultant small gain in the hay crop.

784. The Cowpea as a Green Manure. The cowpea is an important green manure and catch crop in parts of the South. For this purpose the plant is usually seeded in corn, disked in the stubble of the small grain crop, or sown as the main crop in orchards, or on very poor land to be turned under either in the fall or in the spring for green manure purposes. The root system of the cowpea plant is fairly extensive. (222)

Mooers[8] at the Tennessee Station reports an experiment in which corn grown continuously yielded 28.6 bushels per acre; corn following cowpeas grown and removed for hay, 34.0 bushels per acre; following cowpeas turned under each fall, 40.8 bushels per acre. The highest average yield, 42.4 bushels per acre, was secured when the cowpea crop was allowed to mature and to remain on the surface of the ground throughout the winter.

FIELD PEAS

785. Description. The field pea (*Pisum arvense*) is supposed to be one of the oldest cultivated crops, native to western Asia from the Mediterranean Sea to the Himalaya Mountains. It was introduced into the United States in very early colonial days (Figure 29).

The field pea is an annual legume with slender stems 2 to 4 feet in length, which usually make a more or less prostrate growth unless planted with some other crop which provides support. The leaf is compound, each leaf bearing two or three pairs of leaflets and a slender branched tendril. The flowers are reddish purple, pink or white, mostly two or three to each flower stalk. The pods are about three inches long, each containing five to nine round seed. The seed are generally brown, although sometimes they vary in color from almost white or light cream to brown, being marbled or mottled, and speckled in certain varieties. Seed of field peas are generally smooth and those of garden peas wrinkled at maturity. Field peas are commonly referred to as Canadian field peas.

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[7] Karper, R. E.—"Progress Report, Substation No. 8, Lubbock, Texas, 1909-1914." *Tex. Agr. Expt. Sta. Bul. 219.* 1917.

[8] Mooers, C. A.—"Influence of Cowpea Crop on Yield of Corn." *Tenn. Agr. Expt. Sta. Bul. 137.* 1927.

786. Adaptation of Field Peas. Field peas are adapted to cool growing seasons. High temperatures are very injurious; therefore, distribution of the crop is limited to the northern states and Canada and to high altitudes in the western states, except as it is grown as a winter crop in some of the southern states. Soils for field peas should be well drained and neither strongly alkaline nor acid.

787. Varieties. The more important varieties are described in publications by Vinall[9] and Hulbert.[10]

Arny and McGinnis report yields of threshed peas secured at the Minnesota station[11] from a number of the more important varieties. Table *787a.*

787a. Varieties compared for seed. Minnesota.

VARIETY	DESCRIPTION OF SEED	2-YR. AV. 1920-1921 BUSHELS	4-YR. AV. 1920-1923 BUSHELS
Golden Vine	Small yellow	29.58	23.46
Marrowfat	Large yellow	19.53	19.43
Blue Prussian		26.88	24.78
Meyer	Small yellow	16.96	....
Solo	Medium gray, green stippled, purple	26.55	....
Chang	Medium yellow, Black hilum	18.19	....
Least significant difference		2.05	3.70

788. Uses of the Crop. Field peas are grown for seed, as a hay crop and in some sections for silage for pasture and as a green manure or cover crop.

Field peas are not used extensively for silage or for green manure, due to the relatively high cost of the seed. When seeded with oats they make a silage which is somewhat higher in feeding value than corn silage. Though field peas are often pastured off there is usually considerable waste. When used for this purpose the animals are turned in when the seed have become hard. Hogs and lambs have been reported to fatten rather rapidly on field peas pasture. When harvested for seed, the crop is cut with an ordinary mowing machine when the pods are fully mature and the seeds are beginning to harden. It is shocked in small bunches for curing and may be threshed with the ordinary grain separator. In some of the northern states and particularly in the northeastern states field peas are commonly grown in mixtures with oats or some other small grain for hay. The feeding value of pea hay is quite high. Peas are cut for hay when the first pods are full grown but not filled. Cutting may be delayed, however, until the leaves begin to turn yellow.

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[9] Vinall, H. N.—"The Field Peas as a Forage Crop." *U. S. Dept. Agr. Farmers Bul. 690.* Rev. ed. 1917.

[10] Hulbert, H. W.—"Field Pea Production in North Idaho." *Idaho Agr. Expt. Sta. Bul. 115.* 1919.

[11] Arny, A. C., and McGinnis, F. W.—"Field Crop Variety Trials on the Coon Creek Peat Experimental Fields, 1919-1925." *Minn. Agr. Expt. Sta. Bul.* 228. 1926.

Mortimer[12] reports yields of hay secured at the Wisconsin Station from various mixtures of peas and oats. Seeding a bushel and a half of oats per acre, the rate of seeding the peas varied from 90 to 150 pounds. The yields of air-dry hay ranged from 2.32 tons per acre to 2.55, the largest yield being secured when 120 pounds of peas were used with the oats.

Vinall states that when field peas are grown in mixtures in humid sections, one bushel of peas to one or one and one-half bushels of oats is desirable; for dry sections the proportion should be reversed.

789. Culture of the Crop. Field peas must be planted very early in the spring. The young plants will not be harmed by light frost. Seeding is usually done with a grain drill, planting from 2 to 4 inches in depth. Hulbert reports the average yields for a three-year period, from 5-inch, 3½-inch and 2½-inch depths of seeding. When seeded early the five-inch seeding yielded 30.5 bushels per acre; the three and one-half inch, 36.3 bushels; and the two and one-half inch, 32.7 bushels. When seeded only medium early the differences were in the same order but not so great.

Vinall states that with varieties like the Golden Vine the rate should be from 1½ to 2 bushels per acre; with medium sized beans, 2 to 2½ bushels; with large beans such as the Marrowfat, 3 to 3½ bushels per acre. These rates are for plantings in humid sections or under irrigation. Under dry conditions the rate of seeding each variety is decreased about ½ bushel per acre.

Hulbert seeded peas in Idaho, drilling the crop at the rate of 60, 75, 90, 105, and 120 pounds per acre. As a four-year average, the yields were 31, 29.2, 33.6, 29.9, and 31.5 bushels per acre. Hulbert also compared peas drilled solid as compared to seeding in 18-inch and 24-inch rows. The yields were practically identical. In the drier sections, planting in rows has shown a slight advantage, but under average conditions drilled peas have usually given the best results.

VELVET BEANS

The velvet bean (*Stizolobium deeringianum*)[13] is of relatively recent introduction but it has made rapid gains in acreage in the southern states, where it is suited (Figure 30).

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[12] Mortimer, G. B.—"Emergency Hay Crops." *Wis. Agr. Expt. Sta. Bul. 359.* 1924.

[13] Piper, C. V., and Morse, W. J.—"The Velvet Bean." *U. S. Dept. Agr. Farmers' Bul. 1276.* 1922.

790. Description and Varieties. The velvet bean is an annual legume with a much-branched, viny stem, which, under favorable conditions, may attain a length of 30 to 50 feet. The leaves are petioled and trifoliate. Each leaf is attached to a short pubescent stalk. The flowers are borne in long, pendant racemes and vary in color from white to purple, depending upon the variety. The seed pods vary from two or six inches in length and are covered with a black velvety pubescence in certain varieties and a grayish or whitish or even yellow pubescence in others. Some of the more important varieties are the following: Florida, Georgia, Alabama, Chinese, Osceola, Yokohama and the Lyon.

The varieties Florida, Georgia, and Alabama are very similar and the seed of these varieties cannot be distinguished. However, the Georgia variety matures in 120 days and the Alabama in 160 days, while the Florida requires 180 days. Georgia and Alabama represent earlier maturing selections from the Florida.

791. Adaptation of the Velvet Bean. The velvet bean is especially well adapted to well-drained portions of the Atlantic and Gulf Coastal Plains. The culture of the crop has been extended through the introduction of new varieties until at present it is grown over all except the extreme northern portion of the cotton belt. The velvet bean is not well suited to growing in cold, wet soils.

792. Culture of the Crop. Seeding of the velvet bean is best delayed until the soil is well warmed up in the early summer. It is usually planted with corn or with some other supporting crop, owing to the viny, trailing nature of the plant growth. The rate of seeding varies according to the method of seeding, two to three quarts of seed per acre being required when planted with corn. The amount of seed required per acre also varies somewhat with the variety.

793. Uses of the Crop. Ninety per cent of the velvet bean acreage is grown in connection with corn, so its use as hay is rather limited. The hay is coarse and is not easily cured out. The most important use of the velvet bean is as a pasture or grazing crop for cattle and hogs in the autumn and winter.

When grown for seed the pods are picked by hand, when they are thoroughly dry and ripe. A good average yield when planted in corn would be 1000 pounds per acre of beans in the pod. This is equal to a yield of 10 or 11 bushels of shelled beans per acre. Yields as high as a ton and a half per acre of beans in the pod have been reported though such yields are secured only under the very best conditions.

The velvet bean is also one of the best soil-improving crops in the South. It will grow well on a great variety of soils, including soils very deficient in lime.

FIELD BEANS

Field beans (*Phaseolus vulgaris*)[14] were grown on 1,600,000 acres of land in the United States in 1926. The average yield per acre was 10.3 bushels and the farm value per bushel $2.92. The total farm value of the crop was approximately $50,000,000. The principal states in the production of field beans are Michigan, Colorado, New Mexico, California, New York, Idaho, Montana, and Wisconsin (Figure 28).

794. Varieties of Field Beans. Cox and Pettigrove[15] state that the leading variety in Michigan is the White Navy, which constitutes 90 per cent of the Michigan crop with the red kidney bean second, constituting 8 per cent of the crop. The remainder of the crop is made up of brown Swedish, white kidney, Boston Yelloweye, and soup beans. The common white bean or navy bean is of American origin and the name "navy" became applied to the bean because of the demand for this bean as a naval and marine food supply. The Robust bean is a variety of the pea type developed by Professor Spragg at the Michigan Experiment Station. It is partially resistant to blight and anthracnose, and apparently immune to the mosaic disease.

795. Planting. Cox and Pettigrove state that the time of planting beans in Michigan ranges from May 25 to June 25 and in general the recommendation is made that they be planted when the seedbed is well warmed up. They are usually planted in drill rows from 36 to 38 inches apart. For the Robust or the navy beans, 35 to 45 pounds per acre are required and from 40 to 50 pounds of kidney beans. Beans require careful and thorough cultivation.

796. Harvesting and Threshing. The bean harvester, as used at present, consists of a frame on wheels which carries two heavy knives, which cut the bean plants just beneath the surface of the ground, pulling and throwing together two rows of beans at a time. The harvesting is done when the plants are mature, care being taken that they are not too ripe. The beans are pitched into piles in the field or raked into windrows and when well wilted are placed in small cocks for curing. For threshing, a special bean separator is generally used. This bean thresher has two cylinders, the first operated at a low speed and the second at a comparatively high speed. This machine is sometimes used for threshing soybeans and cowpeas also. By making some adjustments an ordinary grain separator may be used for threshing beans.

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[14] Stewart, George—"Field Beans." *Utah Agr. Expt. Sta. Circ. 37.* 1919.

[15] Cox, J. F., and Pettigrove, H. R.—"Bean Growing in Michigan." *Mich. Agr. Expt. Sta. Spec. Bul. 129.* 1924.

PEANUTS

The peanut (*Arachis hypogaea*) is locally known as the "goober" in the South. Alabama, Virginia, Georgia, and North Carolina are the most important states in the production of peanuts. The crop is grown generally over the South extending as far north as the limits of cotton production. The Spanish peanut may be grown successfully as far north as the central corn belt (Figure 28).

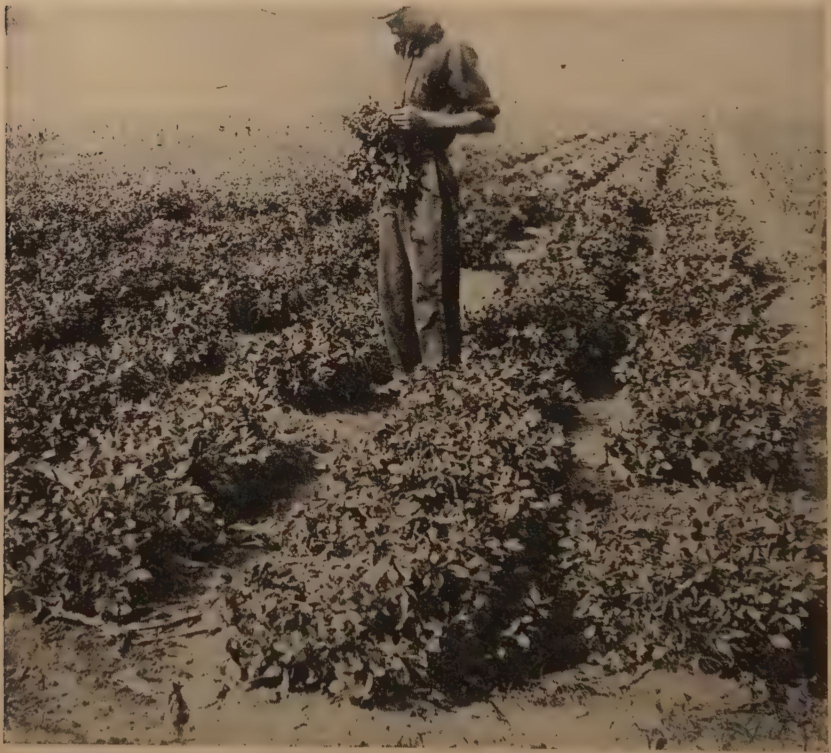

FIG. 143.—A good growth of Spanish peanuts in Illinois. *What is the range of adaptation of this variety? Under what conditions may this crop be planted and harvested profitably with hogs?*

797. Description of the Plant. The peanut is an annual legume, the plant growing from 1 to 2 feet in height. Some varieties are erect, while in others the branches lie practically flat on the ground. The stems are covered with pubescence or hair and are angular in cross sections. The flowers are small, yellow, or orange colored, borne in the axis of the leaves. Male and female flowers are separate on the plant. After fertilization, the stem or peduncle bearing the ovary elongates and turns downward, entering the soil. If this peduncle or "peg" cannot enter the soil no pods are produced.

798. Adaptation of the Crop. Most varieties of peanuts require a 100 to 140-day frost-free season. They prefer a relatively high temperature with moderate moisture. For market purposes, light, sandy soil is best adapted to the production of peanuts; as heavy soils, particularly clay soils, make harvesting difficult.

799. Varieties of Peanuts. There are two general types of peanuts. In the large kerneled sort, most of which have a spreading habit of growth, the nuts are borne along the stems and at the base of the plants. The outstanding varieties of this sort are the Virginia Runner, or Jumbo, the North Carolinian, and the African. They are grown generally for home use. The Virginia Bunch also has large pods and nuts, but the plant makes a more upright growth, and the nuts are borne in clusters around the base.

The other type of peanut is the small bunch type characterized by the Tennessee Red, the Georgia Red, the Valencia, the Spanish, and various other selections. These are all erect growing, with the nuts borne in clusters around the base of the plant. The Spanish and the Spanish selections are the most important varieties commercially. The pods are small, usually containing two kernels, with the hull light brown or pink in color. The Valencia and the Tennessee Red have a bright red hull and for this reason are not considered desirable for milling purposes. The large podded varieties of peanuts usually weigh 22 pounds to the bushel, while those of the Spanish type weigh approximately 28 to 30 pounds to the bushel.

Batten[16] has reported the number of nuts required to make one pound of shelled nuts in a number of different varieties. The Virginia Runner required 195; the Virginia Bunch, 165, and the Spanish, 365. In shelling these three varieties the per cent of hulls was 14.7 in the Virginia Runner, 26.9 in the Virginia Bunch, and 17.7 in the Spanish.

Large podded sorts of peanuts are commonly grown in the northern and eastern sections of the peanut belt, while in the southern and western sections the Spanish types are most commonly grown, particularly in the Southwest, because of the fact that they are hardy and drouth-resistant.

800. Culture of Peanuts. Peanuts are planted as soon as the soil is warmed up in the spring. The earlier plantings yield best, although early maturing sorts such as the Spanish type may be planted as late as July 1 in the southern part of the belt. In planting peanuts the field is usually worked down level, the fertilizer to be applied is broadcast, worked in, and the land marked off. The seed is planted with a special planter which usually handles only one row at a time. Quite commonly peanuts are dropped by hand. Rows usually vary from 30 to 42 inches apart, 36 inches being common. The large kerneled sorts with the more or less decumbent growth are usually planted in rows 34 to 42 inches apart and with the nuts spaced 12 to 18 inches in the row, while with the bunch varieties the rows are spaced 32 to 40 inches with the nuts 7 to 12 inches in the row.

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[16] Batten, E. T.—"Peanut Culture." *Va. Agr. Expt. Sta. Bul. 218.* 1918.

McNess[17] reports a test in Texas in which 18-inch rows were compared to 36-inch rows for the Spanish peanuts. The yield, as a 3-year average, was 32.0 bushels per acre for the 18-inch rows and 30.0 bushels for the 36-inch rows. The yield of cured forage was 0.54 ton for the 18-inch rows and 0.59 ton for the 36-inch rows.

He reports a test at Lubbock, Texas, in which the Spanish variety was used with the plants variously spaced in the row. Six-year average yields of nuts and forage were as shown in Table *800a*.

800a. Spacing of Spanish peanuts. Texas.

SPACING IN THE ROW—INCHES	SIX-YEAR AVERAGE YIELDS	
	Nuts (Bushels)	Forage (Tons)
6	49.6	1.78
9	45.4	1.62
12	42.0	1.51
15	39.8	1.20
18	35.1	1.34

In a three-year coöperative test between the United States Department of Agriculture and the South Carolina Agricultural Experiment Station, peanuts were planted with spacings varying from 3 to 18 inches in the rows. The closer spacings produced the higher yield of nuts and forage and the yields gradually declined as the distance between plants increased.[18]

From 32 to 48 pounds of Spanish peanuts in the shell are required to plant an acre, depending upon the planting distance; of shelled nuts from 23 to 34 pounds are required per acre. Of the large podded varieties 30 to 34 pounds per acre are required. Seed must be handled carefully after being shelled as the breaking of the thin hull on the outside of the nut affects the germination. The nuts are planted whole, broken in two or shelled by hand. In some sections the seed is treated before being planted, various materials being used, in order to repel moles and other rodents which destroy the seed after planting. The nuts are planted 1½ to 2½ inches in depth, depending upon the soil type. Shallow cultivation is practiced until the plants begin to "peg" down. Usually loose soil is thrown toward the plants at the last cultivation so that the "pegs" may enter loose soil rather than meet a hard crust. Formerly it was considered necessary to shovel dirt into the center of the peanut plant in order to cover the nut. This lowers the quality of the hay produced and it is doubtful whether it has any benefit particularly with the erect growing types.

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[17] McNess, Geo. T.—"Peanuts in Texas." *Tex. Agr. Expt. Sta. Bul. 381*. 1928.

[18] Beattie, J. H., *et al.*—"Effect of Planting Distances and Time of Shelling Seed on Peanut Yields." *U. S. Dept. Agr. Dept. Bul. 1478*. 1927.

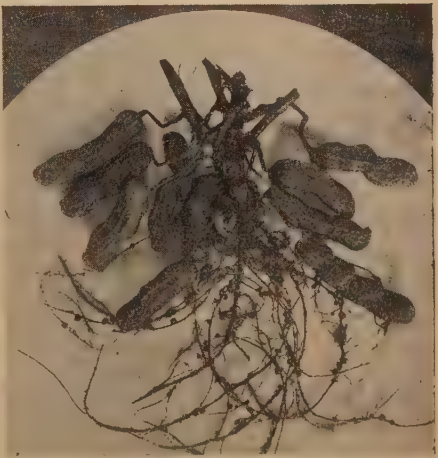

Fig. 144.—Peanut roots and crown with nuts and nodules attached. *The nodules would indicate that the peanut is a legume. Under what conditions may it be regarded as a soil improving crop?*

801. **Harvesting.** For seed, peanuts are harvested with several types of pickers, most of which loosen the plant in the soil, running just below the nuts. Harvesting is sometimes done with an ordinary potato digger and in certain sections they have been harvested with the plow. When harvested in this way the greater portions of the root system is taken out of the ground, including the nodules, so that, while the peanut is a legume, its growth has little effect on soil fertility. The nuts being loosened in the soil, the peanut vines are lifted and the soil shaken off and after they have become well wilted may be stacked. Peanuts are stacked around a pole with a crossbar at the bottom which keeps the plants up off the ground, the stack being made very slender with the nuts on the inside. Peanuts are usually allowed to cure in the stack for a period of six weeks, after which the nuts are removed from the plants, usually with picking machines, though much of this is done by hand.

Market grades of peanuts have been established by the trade. Four classes generally recognized are the "White Spanish," "Bunch," "Runners," and "Mixed" with three grades (one, two, and three) in each class. The grade is determined largely by the per cent of mature kernels and by the per cent of damaged kernels. Excessive moisture, discolored hulls, mixtures of varieties and shelled nuts may make the class off-grade, in which case they are sold by sample only.

Peanut hay is often made from the vines after the pods have been removed. Such hay is usually of high quality, comparing favorably with clover and alfalfa hay.

802. Peanuts as a Feed for Hogs. Peanuts are one of the most profitable hog feeds on southern farms, in spite of the fact that, like the soybean when fed in large quantities, they produce so-called "soft pork." The yield of peanuts varies from 25 to as high as 150 bushels per acre. The average yield in the United States in 1926 was 735 pounds per acre. A bushel of Spanish peanuts, weighing 28 pounds, produces about one gallon of oil, worth 45 cents, and 20 pounds of oil cake and hull, which when ground and mixed together will be worth approximately 25 cents. The oil content of peanuts of the Spanish variety is frequently as high as 45 per cent. Peanut oil is in the same class with cottonseed oil and olive oil. The peanut as a human food is eaten roasted, as salted shelled nuts, or in the so-called peanut candies and brittles and in certain combinations of popcorn and puffed rice; also in the form of peanut butter and as an ingredient in peanut vegetable meat, peanut meal, and salad oil.

STUDY QUESTIONS ON CHAPTER XXX

1. Prepare an outline listing the distinguishing characteristics of the plant and of the seed of the following large seeded legumes: cow pea, field pea, velvet bean and field or soup bean.
2. What is the climatic and the geographic distribution of the above legumes as represented by their economic production?
3. Outline in order of importance the different ways in which these different legumes are used.
4. Give instructions for the production and the harvesting of a crop of cow peas. A crop of field peas. A crop of velvet beans. A crop of field beans.
5. Account, if possible, for the relatively greater use which has been made of the cow pea as a crop to be seeded alone in the South, as compared with the other large seeded legumes.
6. Over what part of the United States is the peanut regarded as an economic crop?
7. What soil is most ideally adapted to the growing of the peanut? What is the range of soil conditions under which it may be grown with reasonable success?
8. Describe the different types of peanuts; state the sections where produced on an economic scale and the use made of each type.
9. Give the necessary instructions for the growing and harvesting of a crop of peanuts.

APPLICATION ASSIGNMENTS ON CHAPTER XXX

1. You live in north central Wisconsin where you are farming a sandy loam soil. You wish to grow a legume crop other than soybeans, the seed of which you can dispose of readily as a cash crop. What will you grow? Give instructions covering the essentials of production.

2. Operating a farm in northern Iowa you wish to seed a legume in mixture with oats, the combined crop to be cut for hay. What legume will you use? What variety will you use in a mixture to seed with the Green Russian oat? What will be the rate of seeding of each and when will you seed?
3. Farming a sandy soil in southern Tennessee you want a legume which you can grow as a cash crop. What crop will you use? Give instructions for handling the crop.
4. You are planning to plant corn in southern Mississippi, the crop to be harvested with stock at the end of the season. What legume will you plant with the corn? Give instructions for the planting, including varieties, rate, time and method of seeding.
5. A planter in east Texas wants to seed one of the annual legumes, the crop to be harvested for hay. What will you recommend? Give instructions for the growing of the crop.

CHAPTER XXXI

THE SORGHUMS

The sorghums constitute a very important grain crop over a considerable area and an important forage in a much larger part of the country. The growing of sorghum for sirup also represents a considerable industry, while the broom corn crop is important in limited areas.

803. History and Distribution. Sorghum (*Andropogon sorghum; variety vulgare*) was cultivated in Egypt as early as 2000 B.C. and is now cultivated also in Africa, India, China, and Manchuria. It was introduced into the United States from Africa about 1850.

There are several distinct types of sorghum differing greatly in their characteristics. On account of their drouth-resistant qualities, the grain sorghums have become very important in the southern Great Plains area, Kansas, Oklahoma, Texas, and the eastern portion of Colorado and New Mexico, extending somewhat into southern Nebraska. The sweet sorghums have also spread generally over the country, being grown extensively for fodder and for the making of sirup. In 1919, there were about 9,000,000 acres devoted to sorghum in the United States, of which a little over 3,500,000 were harvested for grain and 4,500,000 for fodder, while about a half million acres were used for sirup production and a third of a million acres were given to broom corn.

804. Adaptation of Sorghum. Sorghum does best in the southern half of the United States where the temperature is uniformly high during the growing season. Vinall and Reed[1] state that the date of planting should be so arranged that germination and early growth of the plants will take place during the period of high temperatures and the flowering and fruiting when more moderate temperatures prevail.

Sorghum is not so exacting in moisture requirements as it is in temperature relations. It is grown successfully in dry regions having 15 to 25 inches of rainfall, not because it will not grow better in regions having heavier rainfall, but because it will do better than other crops under conditions of light rainfall. In the more moist sections the grain sorghums cannot successfully compete with corn. Sorghums prefer a fertile sandy loam soil, though a fair crop can be produced on heavy soils if they are well drained. Land too poor or thin to grow corn or wheat is often seeded to sorghum. Under these conditions the grain sorghums are usually not very successful though the sweet sorghums grown for forage purposes often produce a good crop of hay.

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[1] Vinall, H. N., and Reed, H. R.—"Effect of Temperature and Other Meteorological Factors on the Growth of Sorghums." *Jour. Agr. Res.* Vol. 13, No. 2, p. 147. Apr. 8, 1918.

805. Description of the Plant. Sorghum plants vary in height from 4 to 12 and 15 feet. The size of the stem varies from less than 1 inch to as much as 2 inches in thickness. The length of internode varies from 4 to better than 12 inches. The stem resembles corn in the arrangement of leaves and the appearance of the leaves and of the growing plant. The panicle corresponds to the tassel in corn and varies from a small, compact panicle with short side branches to the extremely long branched panicles of broom corn. The leaves of the sorghums are strong and well adapted to withstand dry weather. At times of drouth the leaves assume a rather erect position and the edges roll together. The extremely drouth-resistant types such as the Milo and Durra have a relatively small leaf surface.

806. Pollination and Mixing of Varieties. Ball[2] states that in adjacent rows of sorghum of different varieties flowering on approximately the same date, as high as 50 per cent of the seed produced on the leeward row was found to be cross-fertilized.

Karper and Conner[3] report that where a pure strain of milo is grown near to and flowering at the same time as another field which might contaminate it, the amount of crossing in the outer rows would undoubtedly not exceed three per cent. Where white milo plants were entirely surrounded by plants of the yellow milo, six per cent of cross-fertilization occurred.

807. Classification. Botanically, the sorghums belong to the family *gramineae* along with the other grasses. They belong to the tribe *Andropogoneae,* to the genus *Andropogon* and to the species *sorghum.* The botanical name, according to Hackel, is *Andropogon sorghum;* variety, *vulgaris.* All of the sorghums are generally believed to have originated from *Andropogon halepensis,* a persistant perennial, winter hardy in the southern states, where it is known as Johnson grass and to which Sudan grass is closely related. In 1910, Ball[4] suggested the following classification of the principal groups of sorghum.

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[2] Ball, Carleton R.—"The Breeding of Grain Sorghums." *Amer. Breeders Assn. Rpt.* Vol. 6, p. 193. 1909.

[3] Karper, R. E., and Conner, A. B.—"Natural Cross-Pollination in Milo." *Jour. Amer. Soc. Agron.* Vol. 11, No. 6, p. 259. Sept. 15, 1919.

[4] Ball, Carleton R.—"The History and Distribution of Sorghum." *U. S. Dept Agr. Bur. Plant Indus Bul. 175.* 1910.

I. Pith juicy.
  A. Juice abundant and sweet.
        Sweet sorghums (Sorgo)
  B. Juice scanty, slightly sweet to sub-acid.
    1. Internodes short—12 to 15 leaves. Pedicels erect, cylindrical panicles, lemmas awnless.
        Kafir
    2. Internodes medium, 8 to 11 leaves, pedicels mostly inclined, ovate panicles, lemmas awned.
        Milo
II. Pith dry.
  A. Panicle lax (loose and spreading), pedicels erect, lemmas awned.
    1. Panicle 4-7 dm. long.
        Broom corn
    2. Panicle 2.5 to 4 dm. long.
      a. Panicle conical, branches drooping.
        Shallu
      b. Panicle oval or ovate, branches spreading.
        Kaoliang
  B. Panicle compact 1 to 2.5 dm. long, pedicles erect or recurved.
    1. Spikelets elliptic oval, 2.5 to 3.5 mm. wide, lemmas awned.
        Kaoliang
    2. Spikelets broadly obovate, 4.5 to 6 mm. wide.
      a. Glumes gray or greenish, smooth, hairy, seeds flattened.
        Durra
      b. Glumes deep brown or black, wrinkled, thinly pubescent, seeds slightly flattened.
        Milo

Grain Sorghums

The proportion of the sorghum acreage harvested for grain, for forage, for sirup, and for the brush has been shown. (803)

As has been stated, grain sorghums cannot compete successfully with corn in regions of abundant rainfall, but are grown extensively where the rainfall or other environmental conditions are unfavorable to corn (Figure 30).

808. Corn and Grain Sorghum Compared. In feeding studies at the Texas Agricultural Experiment Station, continued through a 5-year period, when the feeding value of ground corn was taken as 100, the relative productive value of the various sorghums compared with corn was found to be as follows: ground feterita, 96; ground feterita heads, 87; ground kafir, 98; ground kafir heads, 84; ground milo, 99; ground milo heads, 92; whole milo, 94; darso chops, 94; sweet sorghum chops, 92.[5]

The returns from an acre of sweet sorghum, of corn, and of kafir corn, each harvested for silage, were compared at the Kansas Agricultural Experiment Station.[6] As a 5-year average (1912-1916, inclusive) the sweet sorghum produced 18.02 tons per acre; the corn, 11.81 tons; and the kafir, 11.86 tons. An acre of sweet sorghum is credited with the production of 3750 gallons of milk; the corn, 2750 gallons; and the kafir, 2719 gallons, per acre. In another comparison an acre of sweet sorghum produced 1718 pounds of meat; corn, 1315 pounds; and kafir, 1253 pounds. (499) (500)

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[5] Jones, J. M., and Dickson, R. E.—"Grain Sorghums *vs.* Corn for Fattening Lambs." *Tex. Agr. Expt. Sta. Bul. 379*, p. 45. 1928.

[6] Cunningham, C. C., and Kenney, Ralph—"Growing Sorghum in Kansas." *Kans. Agr. Expt. Sta. Bul. 218.* 1917.

The analysis of corn, kafir, and sorgo as fodder and as silage has been reported by Vinall and Getty,[7] as shown in Table *808a.*

808a. Composition of corn, kafir, and sorgo forage.

CROP	NUMBER OF ANALYSES	CONSTITUENTS (PER CENT)					
		Water	Ash	Crude Protein	Fiber	Nitrogen-Free Extract	Fat
Field-cured fodder:							
Corn	23	39.3	3.6	4.8	16.7	34.2	1.4
Kafir	20	40.0	6.2	5.9	17.7	28.4	1.8
Sorgo	11	37.4	3.1	3.9	17.8	35.0	2.8
Silage from fairly mature plants:							
Corn	121	73.7	1.7	2.1	6.3	15.4	.8
Kafir	3	69.2	2.5	1.8	9.9	15.5	1.1
Sorgo	30	77.2	1.6	1.5	6.9	11.9	.9

809. During a period of 8 years Ball and Rothgeb[8] analyzed samples of sorghum seed and 86 samples of dent corn. The comparative averages of the sorghum and the corn are as follows: water, 9.41 and 10.60 per cent; ash, 1.69 and 1.50 per cent; protein, 13.13 and 10.30 per cent; carbohydrates, 70.91 and 70.40 per cent; fiber, 1.53 and 2.20 per cent; and fat, 3.30 and 5.00 per cent, respectively.

As a human food, the sorghum may be ground into meal and used for practically all purposes to which corn meal is adapted.

810. Groups and Varieties of Grain Sorghums. There are several rather distinct groups of the grain sorghums as milo-durra, kafir, kaoliang and shallu.

The milo-durra group. This group of sorghums is characterized by an oval to ovate panicle, short branched, compact; seed borne in spikelets; seed broadly flattened, 4½ to 6 mm. wide. To this group belong the white and brown durra, white and yellow milo, and feterita. Durras require about 95 days to mature. They vary in height from 4 to 7 feet. They are not commercially important in this country.

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[7] Vinall, H. N., and Getty, R. E.—"Growing and Utilizing Sorghums for Forage." *U. S. Dept. Agr. Farmers' Bul. 1158.* 1920.

[8] Ball, Carleton R., and Rothgeb, Benton E.—"How to Use Sorghum Grain." *U. S. Dept. Agr. Farmers' Bul. 972.* 1918.

The milos mature in from 70 to 80 days. There are two general classes of milo,—yellow and white. There are also two types of milo, one being called standard or the old type milo or giant milo and the other dwarf milo. The chief difference is in height. Milo is inclined to have some pendant heads. Ball and Rothgeb[9] state that as an average for a 9-year period the height of dwarf milo in the Great Plains was 3 feet when the standard milo averaged 4 feet. The outstanding characteristic of dwarf milo is its ability to produce good yields under the conditions of the western Great Plains area.

FIG. 145.—A planting of kafir corn in Iowa. *Under what conditions can this crop compete successfully with corn?*

Feterita panicles are elongated and elliptical rather than ovate, somewhat less compact than milo, and always erect. The seeds are chalky white or sometimes bluish white in color. The feterita averages about 5 feet in height and the plant tillers readily. There are three general types of feterita, dwarf, standard, and spur.

811. The Kafir Group. In the kafir group the stems are stout and semi-juicy; the leaves broad and dark green; the panicles erect, cylindrical, lemmas not awned, seeds midsize to small. The principal varieties are black hull,—two selections from the black hull, the Dawn and the Sunrise,—white, pink, and red kafir. The growing season for kafir is generally from 100 to 120 days. The normal height for the southern Great Plains conditions is 5 feet. In sections with heavier rainfall the height is somewhat greater than this. The seed of black hull kafir are white with pink or reddish spots. The glumes are black. The Sunrise kafir is really early black hull kafir. It is somewhat taller than black hull. Dawn kafir matures about the same time as Sunrise kafir, but is somewhat shorter and is better adapted to hand heading.

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[9] Ball, Carleton R., and Rothgeb, Benton E.—"Grain Sorghum Experiments in the Panhandle of Texas." *U. S. Dept. Agr. Dept. Bul. 698.* p. 36. 1918.

White kafir has white or pale glumes instead of black. It has a long slender head with white glumes mixed with red, while the seed is white with red spots of varying size. Red kafir resembles white kafir except for its red seeds and glumes. Pink kafir is grown to a certain extent in Kansas, but is not commercially important in other sections.

812. Kaoliangs. A large assortment of varieties is classified in this group, varying from early to late, and from dwarf to tall. Some have compact panicles while in others the heads are lax as in the case of the sweet sorghums. Large-seeded and small-seeded types are also found. All types have small to medium stalks, containing dry pith. The plants bear comparatively few leaves. For this reason it is not as valuable as the other varieties for forage purposes. The late varieties are usually tall with scant forage. Ball[10] states that the real need at present is for the very early strains of kaoliang only, which mature farther north and at higher altitudes than the milos.

Black hull kaoliang has given rather consistently good yields at the Woodward Station in Oklahoma. This selection is a small white-seeded, compact-headed type. It matures in about 110 days. Sieglinger[11] states that the kaoliangs are the only sorghums which have never yielded less than 10 bushels per acre at the Woodward field, but that on the other hand the yields have never been very high.

813. Shallu Group. The fourth group of grain sorghums, the shallu, have been exploited under various names,—California wheat, Egyptian wheat, desert wheat, etc. The heads of shallu are large and spreading, being wide at the base and somewhat narrow at the top. They are pale yellow in color. The stalks are dry and pithy and practically valueless as forage. The plants are slender and vary from 5 to 8 feet in height. Tests at Woodward, Oklahoma, and at other stations in the Great Plains have indicated that the plant has been very much over-advertised, as it has little agricultural value.

814. Other Sorghums. Several other grain sorghums, largely placed in indefinite groups, are grown commercially in certain sections. Some of these give promise of being grown extensively.

Darso is a dwarf sorghum plant, supposedly a cross between sweet sorghum and grain sorghum. It averages about four feet in height, has heavy foliage with large stalks usually tinted with red. The heads are rather loose, 10 to 12 inches long, and do not shatter readily. The percentage of sugar in the juice of the plant is much higher than in either black hull kafir or feterita. This variety has been developed by the Oklahoma Agricultural Experiment Station.

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[10] Ball, Carleton R.—"Kaoliangs." *U. S. Dept. Agr. Bu. Plant Indus. Bul. 253.* 1913.

[11] Sieglinger, John B.—"Grain Sorghum Experiments at the Woodward Field Station in Oklahoma." *U. S. Dept. Agr. Dept. Bul. 1175.* 1923.

Beeson and Daane[12] state that in variety tests of grain sorghum extending over a period of 6 years the average yield of grain for darso has been 3 bushels more than for any other grain sorghum. The yield of forage was less than for the black-hulled, white or the dwarf Hegari kafir. Darso was found to stand relatively long periods of drouth better than the kafirs.

Schrock kafir is another hybrid between a sweet sorghum and kafir. The seed do not shatter readily. Like sweet sorghum, the seed contains considerable tannin. Schrock kafir made good yields at Woodward, Oklahoma. It requires from 100 to 120 days to mature fully.

Hegari was introduced into the United States from Sudan, Africa. For this a commercial strain known as Dwarf Hegari has been selected. Dwarf Hegari has stout stems, is medium juicy and slightly sweet. This sorghum is grown extensively near Chillicothe, Texas, where it has been found to have a higher[13] forage value than the dwarf milo and is easier to harvest, having erect heads. It is comparatively early in maturity.

815. Improving the Grain Sorghums. The greatest improvement in grain sorghums has been through selection within varieties for drouth-resistance, earliness, dwarfness of stature, productiveness, erectness of heads, freedom from suckers and branches, and evenness of height. Selection is the principal means of improvement in all types of sorghum, and marked results in uniformity, in particular, have been obtained by continuous selection.

816. Harvesting Grain Sorghums. The grain sorghums are either cut with a corn binder when the head is mature and allowed to cure out in the shock or they may be headed and the heads carefully cured out and then threshed. The heading may be done by hand, men going through the field with a wagon equipped with bump boards the same as in corn picking, cutting off the heads and throwing them into the wagon. Care must be used in curing out head material in order to prevent heating and molding. It is usually cured out by spreading in the open in a thin layer, which will cure in about ten days. When the grain is harvested by heading either by hand or with a grain header, the stalks are left in the field where they are either pastured or turned under. When the crop is cut with a corn binder, the heads may be cut off, cured and threshed, or sometimes the entire bundle is run through the threshing machine.[14] The grain

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[12] Beeson, M. A., and Daane, Adrian—"Darso." *Okla. Agr. Expt. Sta. Bul. 127.* 1919.

[13] *Ibid.*

[14] Martin, John H.—"Harvesting Grain Sorghums." *U. S. Dept. Agr. Farmers' Bul. 1577.* 1928.

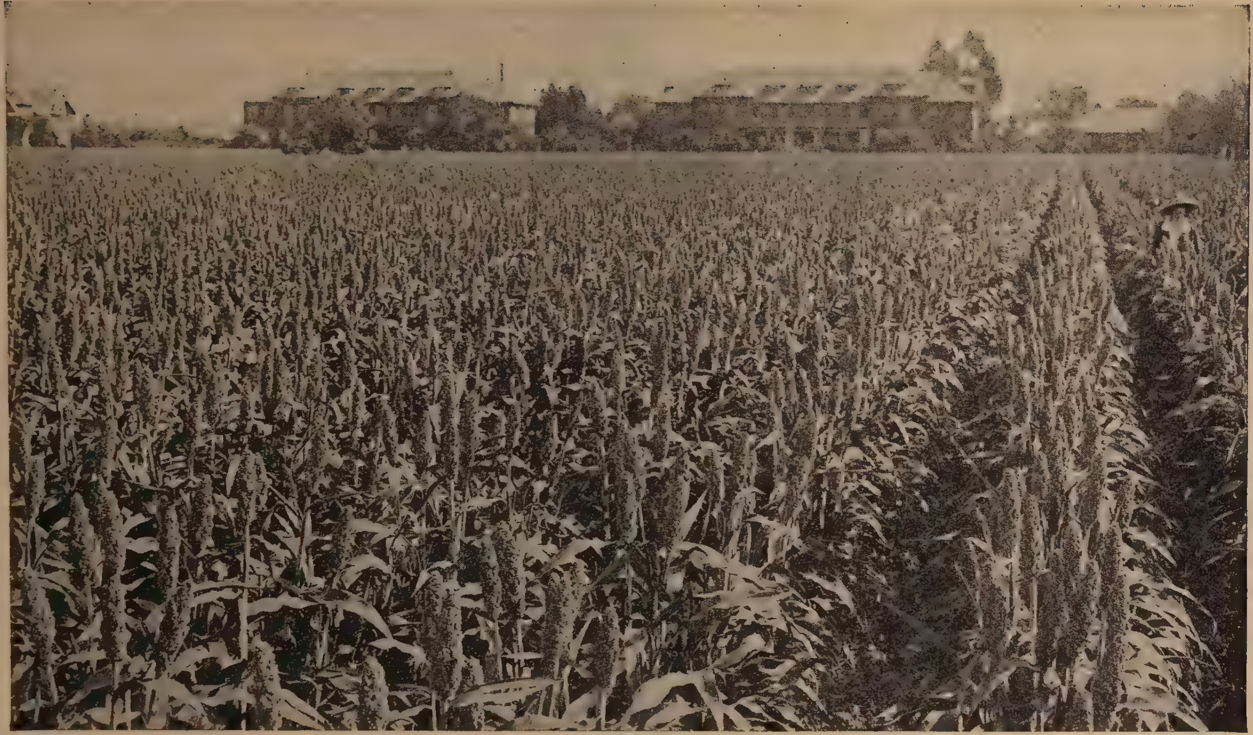

FIG. 146.—A planting of an improved variety of grain sorghum at the California Experiment Station. This sorghum meets the demand for a variety which can be successfully harvested with the header.

separator used in threshing wheat or oats is used in threshing the grain sorghums. Sorghum grain is inclined to heat and care must be taken in storage to prevent this. Screened ventilators are effective if properly placed so as to provide a free passage of air through the grain.

SWEET SORGHUM

Saccharin sorghum was introduced into the United States in about 1853, and for the next 30 or 40 years was used principally for the manufacture of sorghum molasses or sirup. While still grown extensively for sirup, still larger acreages are grown for forage. Sweet sorghum is used for hay, fodder, soiling, and for silage and to a certain extent for pasture. In 1918, 487,000 acres were grown for sirup, and 4,700,000 for forage or fodder purposes (Figure 27).

817. Varieties of Sweet Sorghum. Some of the varieties of sweet sorghum maturing in from 90 to 140 or 150 days, in order of their maturity, are: Black Amber, Red Amber, Orange, Sumac, Honey, and Gooseneck.

Black Amber sorghum is characterized by slender stalks, few narrow leaves, and open branched heads. The seed are elliptical in shape, yellowish brown in color, and nearly enclosed in large, horny, black hulls. *Red Amber* differs from Black Amber in having red instead of black seed hulls and is somewhat later in maturity.

Orange sorghum matures two or three weeks later than Amber, is somewhat taller, the stalks are heavier, the plant is more leafy and the nodes are shorter. The seed heads of the Orange sorghum, which are a deep orange color when ripe, may be classed as compact in comparison with the Amber. Orange is adapted particularly to the region from Kansas south, and the Ambers are grown most extensively from Kansas north.

Sumac sorghum, sometimes called Red Top, is slightly later in maturity than the Orange. The head of Sumac sorghum, like Orange, is somewhat compact and has a characteristic red color. The seed are nearly round and smaller than those of the other sorghums.

Honey sorghum is a large, sweet, leafy sorghum well adapted in the South for either sirup or forage. It is later in maturity than the other varieties described. The head of Honey sorghum resembles that of Red Amber, although usually smaller and less spreading, and has yellowish-brown glumes.

Gooseneck sorghum is sometimes called Texas Ribbon Cane. It is a rather late maturing variety, has heavy stalks, and many of the heads turn downward. It is the largest of all the sweet sorghums, varying in height from 10 to 14 feet. The heads are rather thick and fleshy with shiny black glumes which entirely enclose the seed. A number of other varieties have been developed and tested, but these six may be said to be the standard or type varieties.

818. Harvesting Sweet Sorghum for Forage. When harvesting sweet sorghum which has been grown in rows the corn binder is usually used. The plants may be used for forage, fodder, or silage. Where the sorghum is seeded solid it is cut and handled much as other hay crops, though it is sometimes handled with a grain binder or with a corn binder and cured in shocks. **(499) (500)**

819. Harvesting Sweet Sorghum for Sirup. Sweet sorghum to be used in the manufacture of sorghum molasses is handled much the same as for silage and harvested when the seed are in the hard dough stage. The first operation in the harvesting process is to strip the leaves from the plant, then the plants are cut, and generally the seed head topped off. Where cane is stripped by hand it is often cut with a corn binder. The stalks are run through rollers which press out the juice, which is allowed to settle, and is then run into shallow cooking vats, where it is boiled down to the desired degree, skimming constantly. Milling should be done within a few days after cutting as the juice of the plant is inclined to sour.[15]

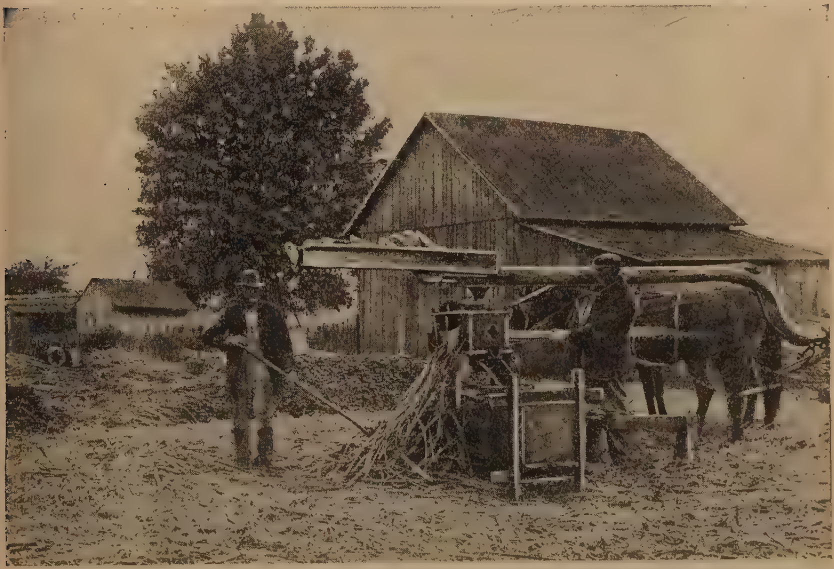

FIG. 147.—A sorghum mill in operation. Most of the sorghum sirup is made in small community mills.

The stalks of sweet sorghums are from 80 to 90 per cent water.

[15] Bryan, A. Hugh—"Sorgo-Sirup Manufacture." *U. S. Dept. Agr. Farmers' Bul. 1389*. 1924.

From 50 to 60 per cent of the juice is usually extracted by a roller cane press. The sugar content of the juice varies from 10 to 18 per cent. Yields of from 60 to 300 gallons of sirup per acre are obtained. A good average yield is 125 gallons. The bagasse constitutes about 40 per cent of the original weight of the wilted stalk. This is used in some sections for feed, although in general it is left to rot. It makes a fair quality of silage when chopped and stored in silos.

Broom Corn

820. Broom Corn. Broom corn is grown only for the brush, which is used in the manufacture of brooms and brushes. The broom corn plant has scant foliage, dry pith, and woody stalks. It has very little forage value. The principal characteristic of broom corn is the short rachis, and the extremely long, slender seed-bearing branch. In the last few years Oklahoma has produced more than half of the broom corn crop of the United States. New Mexico, Illinois, Kansas, Colorado, and Texas are also important in broom corn production.

821. Types and Varieties of Broom Corn. The standard broom corn grows to a height of 8 to 15 feet, with leaves varying from 9 to 11 in number. The heads range from 18 to 24 or more inches in length. The head is well exserted from the boot or upper leaf and firmly attached to the upper node, so that it is necessary to use a knife in harvesting the brush. The fiber is coarse but usually round and pliable.

Dwarf broom corn ranges in height from 3½ to 6 feet, with short internodes. The leaves are narrow and from 10 to 13 per plant. From one-third to one-half of the stem head is enclosed in the upper leaf sheath. The heads are not so firmly attached to the upper nodes as in the standard type and may be harvested by pulling or jerking the heads from the standing stalks.

A number of varietal names are used within each type group of broom corn. In many cases a name does not designate a distinct variety. One outstanding variety is the Acme broom corn, which has been selected from standard broom corn. It has all the characteristics of the standard variety in length and texture of the brush, but has the height only of the dwarf type. Rothgeb and Sieglinger[16] state that the dwarf variety is inclined to sucker more than the standard variety. Suckering is largely influenced by environmental conditions. Environment also influences the length and quality of the brush. A thick stand tends to produce a short brush and a thin stand a long, coarse brush.

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[16] Rothgeb, Benton E., and Sieglinger, John B.—"Broom Corn Experiments at Woodward, Oklahoma." *U. S. Dept. Agr. Dept. Bul. 836*, p. 53. 1920.

822. Planting. In Oklahoma the best time to sow the crop is reported to be either May 1 to 15, or June 15 to 30, so the plant comes into head either before or after the middle of August, which is usually dry and hot. Plants spaced 6 to 8 inches apart in the row with rows 3½ feet apart has been the most profitable rate over a series of years.

823. Broom Corn Seed. Seed threshed from broom corn cut for the brush is not considered desirable to plant as it lacks maturity. In general, it is recommended that growers of broom corn have a plot of broom corn which is left to mature for seed. Careful selection can be made in these plots for desirable types of brush. Two pounds of good seed is usually sufficient to sow an acre in the drier sections. Broom corn is usually planted with an ordinary corn drill or with a lister drill. Special plates for sowing broom corn can be obtained.

824. Harvesting Broom Corn. The heads of dwarf broom corn are jerked or pulled from the upright stalk, while the standard variety is broken over or tabled and the brushes cut off. In this process the tabler walks backward between two rows, bending or breaking the stalks over 3 or 4 feet from the ground and at a 45° angle with the row, the crossed stalks forming a table. The brush is harvested by walking in the space between the tabled rows, cutting the heads from the stalks, which project into these middles. As the heads are cut they are laid in handfuls on the "table," and later gathered on a special wagon rack and hauled to the curing shed. In curing, it is essential that the brush be spread in shallow layers, protected from weathering and allowed a free circulation of air. The seed are threshed from the heads before complete curing by passing the brush end of the heads between horizontal, spiked cylinders which strip the seed off. About three weeks are required to complete the curing of the brush.

825. Grading and Baling Broom Corn.[17] The brush is usually graded before it is baled. After sorting into grades, the brush is taken in small armfuls, butted down evenly at the stem end and alternate handfuls placed in either end of the baler with the stem ends out, the brush part of the heads overlapping the middle. If the bales are to be stored some time before they are marketed they are placed in a dry, dark place in order to prevent staining and bleaching.

826. Returns from Broom Corn. The average yield of broom corn in 1926 was 345.6 pounds per acre. In 1925 it was 264.6 and in 1924, 346.8. Higher yields are obtained in Illinois than in the West. The highest yield obtained in these three years for any one state was Illinois, in which the average yield was 560 pounds per acre. Broom corn is sold by the ton, the prices varying from $20 to $25 per ton for the lower grades in a year in which there is a large supply, to better than $300 per ton in a short crop year. The average price in the United States in 1924 was $95; in 1925, $143; and in 1926, $78.

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[17] Quesenberry, George R., and Will, Ralph R.—"Broom Corn," *N. Mex. Agr. Col. Ext. Circ. 91.* 1926.

GROWING THE SORGHUMS

827. Time of Seeding. Most of the sweet sorghums are warm season plants and should not be seeded too early. In general, the best results are secured from seedings made from 2 to 4 weeks after the ordinary time of planting corn. Quite often the sweet sorghums when grown for hay are drilled or seeded broadcast much later than this time in sections where the growing season permits.

828. Rate of Seeding. The rate of seeding depends upon the use to be made of the crop. Grain sorghums are usually, and sweet sorghums often, seeded in rows with an ordinary corn planter or lister planter, the rows usually being 3 to 3½ feet apart, and the plants varying from 3 to 10 inches in the row. Vinall *et al.*[18] state that the rate of seeding experiments at eight stations in the Great Plains area indicate that a four-inch row space is preferable for forage purposes and an eight to twelve-inch row space for grain. In planting it is well to keep in mind the fact that the germination in the field often averages only about 50 per cent of the laboratory germination.

In experiments in drilling sorghum solid for forage the differences in yield were not great when from 15 to 75 pounds of seed per acre were used. The fifteen-pound rate gave a coarser growth, in a five-year test in Kansas and in two six-year tests in Texas. From these experimental plantings the use of 30 pounds per acre has been recommended for the Great Plains region west of the 100th meridian; 45 pounds between the 98th and 100th meridians; and 60 to 75 pounds east of the 98th meridian.

Cunningham and Kenney [19] state that sorghum for grain is seeded at the rate of 6 to 8 pounds per acre in eastern Kansas and from 3 to 4 pounds per acre in western Kansas. When grown for stover or silage, twice this amount of seed is used. When planted for hay broadcast or with a grain drill, 1 to 2 bushels of seed per acre is used.

Sieglinger [20] found in a 5-year test at the Woodward, Oklahoma, field station that yellow milo yielded highest in rows 44 inches apart with the plants 24 inches apart in the row. With rows 88 inches apart the yield was highest when the plants were 12 inches apart in the row. In 4 out of 5 tests the 44-inch rows outyielded the 88-inch rows. With Sunrise kafir the highest yield was produced when the rows were 44 inches apart and the plants 12 inches apart in the row. The yield was higher in 44-inch rows than in 88-inch rows.

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[18] Vinall, H. N., Getty, R. E., and Cron, A. B.—"Sorghum Experiments on the Great Plains." *U. S. Dept. Agr. Dept. Bul. 1260*, p. 83. 1924.

[19] Cunningham, C. C., and Kenney, Ralph—"Growing Sorghum in Kansas." *Kans. Agr. Expt. Sta. Bul. 218*, p. 38. 1917.

[20] Sieglinger, John B.—"Grain Sorghum Experiments at the Woodward Field Station in Oklahoma." *U. S. Dept. Agr. Dept. Bul. 1175*, pp. 57 and 63. 1923.

829. Method of Seeding. Vinall *et al.*[21] found that in years of low rainfall sweet sorghum planted in rows outyielded that sown in close drills and the quality of forage was superior in the rows seeding. In years of abundant rainfall the reverse was true, the close drilled sorghums outyielded the row seedings. Sorghums when planted in rows are usually seeded with an ordinary corn planter with the plates punched or bored especially for sorghum seed. The ordinary small grain drill is used where sorghum is drilled solid.

Grain sorghums are sometimes drilled solid instead of in rows, though this is not usual. In a one-year test in Texas[22] grain sorghum planted with a grain drill late in the season produced 41 bushels per acre, when the sorghum that was planted in rows and cultivated produced 37 bushels.

830. Sorghum Poisoning. Numerous cases have been reported where cattle have been poisoned by pasturing sweet sorghum and particularly when pasturing sorghum which has been frosted. This is caused by prussic acid, which forms in the plant under certain conditions. Dunstan and Henry[23] were the first to discover that the poisonous effect of sorghum sometimes noted was due to prussic acid. They showed that the prussic acid was not present in the plants as such but originated from the hydrolytic action of an enzyme upon the glucosides present.

Maxwell[24] states that the amount of prussic acid is dependent upon the character of the soil. He also states that sorghum is not fed with safety until the seed begins to develop.

Most workers state that cutting the sorghum and allowing it to cure eliminates the danger of hydrocyanic poisoning. Less trouble is experienced in the southern states than in those farther north. Vinall and Getty[25] state that sorghum forage can be fed with safety and that the prussic acid content of sorghum decreases as the plants approach maturity. Mature plants with ripe seed are seldom dangerous.

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[21] Vinall, H. N., Getty, R. E., and Cron, A. B.—"Sorghum Experiments on the Great Plains." *U. S. Dept. Agr. Dept. Bul. 1260*, p. 84. 1924.

[22] Ross, John F., and Leidigh, A. H.—"Cereal Experiments in the Texas Panhandle." *U. S. Dept. Agr. Bur. Plant Indus. Bul. 283*, p. 35. 1913.

[23] Dunstan, Wyndham R., and Henry, Thomas A.—"Cyanogenesis in Plants. Part 2. The Great Millet (*Sorghum vulgare*)." *Royal Soc.* [*London*] *Phil. Trans.* Ser. A. Vol. 199, pp. 399-410. 1902.

[24] Maxwell, W.—"Sorghum Poisoning." *Queensland Agr. Jour.* Vol. 13, No. 5, pp. 473-474. May 1920. Quoted by Willaman, J. J., and West, R. M. "Notes on the Hydrocyanic Acid Content of Sorghum." *Jour. Agr. Res.* Vol. 4, No. 2, p. 179. May 15, 1915.

[25] Vinall, H. N., and Getty, R. E.—"Growing and Utilizing Sorghums for Forage." *U. S. Dept. Agr. Farmers' Bul. 1158.* 1920.

831. The Effect of Sorghum on the Soil. Vinall and Getty[26] report experiments in Alabama, Arkansas, Kansas, and Nebraska, in which the yield of crops following sorghum was reduced 15 per cent as compared with the yield following corn. At the Kansas station as an average for 3 years, corn after sweet sorghum produced 40.8 bushels; after kafir, 44.0 bushels; and after corn, 54.6 bushels per acre. The acre value of the crops, however, in a 2-year rotation of these three areas was $31.15 for the corn-sweet sorghum rotation, $34.46 for the corn-grain sorghum rotation, and $28.14 for corn after corn. Vinall and Getty state that the most important factor in dry sections, causing the reduction noted in yield is the rather complete exhaustion of the soil moisture by sorghum. (179)

STUDY QUESTIONS ON CHAPTER XXXI

1. Where is the native home of the sorghums? Where are the sorghums grown most extensively in the United States?
2. Describe and distinguish the large groups of sorghums.
3. How does the feeding value of the grain of corn and of kafir compare? Kafir forage and sweet sorghum forage?
4. Why is it that the sorghums are not grown extensively in Indiana and Illinois? Explain.
5. Give instructions for planting a crop of grain sorghum. A crop of sweet sorghum for silage. For hay. For sirup.
6. What is the cause for the variations in the best rates of seeding in the different sections?
7. Outline the method of harvesting a crop of kafir corn for the grain. Sweet sorghum for sirup. Broom corn for the brush.
8. What is the cause of the occasional case of poisoning reported on sorghum pasture? What precautions or remedies can be taken to prevent this poisoning?

APPLICATION ASSIGNMENTS ON CHAPTER XXXI

1. You are farming in west central Kansas and plan to grow sorghum for silage. What sorghum will you use? Why?
2. You are farming in southwest Oklahoma. Your land has been in grain sorghums in previous years and the crop cut for silage. It is in good tilth, not overly firm or hard, and free of weeds. You are planning to plant milo. Will you plow in preparing the seedbed? Explain.
3. Grain sorghum made a good growth but the heads failed to fill properly. What is the probable trouble and the remedy?

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[26] Vinall, H. N., and Getty, R. E.—"Growing and Utilizing Sorghums for Forage." *U. S. Dept. Agr. Farmers' Bul. 1158.* 1920.

4. You have been growing corn but believe that sorghum may give you better results. You secure seed of several different kinds and plant side by side in strips across the field in order to compare them and decide upon the one you wish to continue growing. Can you save pure seed from any one of these plots for the next year's planting? Explain.
5. In planting 20 acres of kafir contrast the methods of production with those you would employ in growing corn.
6. Broom corn is selling for $175 per ton. You are thinking of planting a considerable acreage though it has never been grown in your section before. What facts will influence your decision? Will you grow broom corn?
7. Last year you grew a crop of sorghum for the first time. You have been told that in some cases sorghum does not leave the land in the best condition for cropping the following year. What crop will you plant on this land this season? Explain.
8. You have a 40-acre field of kafir corn ready to harvest. Outline the methods you might use. What method will you probably use? Why?
9. On a map of the United States outline the areas where grain sorghums might be expected to give larger yields of grain than could be had from corn.
10. You have been asked to speak on "Sorghum and Its Use." Write your speech.

CHAPTER XXXII

IMPORTANT PERENNIAL HAY AND PASTURE GRASSES

TIMOTHY

Timothy (*Phleum pratense*) was first cultivated in the United States, although it is native to Europe. It apparently was first grown in the United States in 1747 under the name of Herd grass. It is supposed to have gotten the name "timothy" from Timothy Hansen, who appears to have brought the grass from New England into Maryland. Timothy has long been the most important hay grass in the United States.[1]

832. Description of the Plant. Timothy is a hardy perennial, having erect stems. It is inclined to form tufts or stools, new stalks starting from nodes at the bulbous base of the original stem. Under favorable conditions 10 to 20 shoots may develop from a single shoot in the first year of growth, thus directly or by branching out, forming a stool. Roots are developed at the base of each new shoot. The bulbous growth at the base of each stem is called a haplocorn and it, together with the stem, dies after producing a seed crop. New growth for the next season arises from buds at the lower nodes which start their growth and establish roots before the old growth is dead and which complete their growth in the second season. The root system of the timothy plant is relatively shallow and fibrous.

833. Flowering Habit of Timothy. The inflorescence or head of timothy is called a spike. Evans[2] studied the flowering habits of timothy and found that the flowers on the upper portion of the timothy spike bloom first, those on the lower part of the spike coming into bloom on succeeding days, the last bloom being near the base. The period of blooming covered a period of 6 to 16 days. The greatest number of flowers bloom in the early morning from about midnight to soon after sunrise. The color of a timothy field in bloom varies greatly at different times during the blooming period. The changes are due to changes in the color of the anthers at different times and to the variation in number of flowers which bloom on different days. The popular idea that there are two or more distinct states as a "first and second bloom" or "the blue and the gray bloom" is not correct.

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[1] Evans, M. W.—"Timothy." *U. S. Dept. Agr. Farmers' Bul. 990.* Rev. ed. 1923.

[2] Evans, Morgan W.—"Flowering Habits of Timothy." *Jour. Amer. Soc. Agron.* Vol. 8, No. 5, p. 309. 1916.

834. Adaptation and Uses of Timothy. Timothy is distinctly a northern grass. It does not succeed well in the South as it does not withstand hot, humid summers. It is not drouth-resistant. The range of extensive growth is almost identical with the corn belt (Figure 32).

Timothy's greatest use is as hay and for this purpose it is much more important in the United States than any other cultivated grass. For market it is generally grown alone, but when grown for farm use it is usually grown in mixture with red or alsike clover. The grass is usually seeded in the early spring with a small grain nursecrop, though it may be early fall sown, either alone or with a winter grain. The seed are small and require shallow covering and are, therefore, usually sown broadcast and covered by harrowing. The rate of seeding varies from 10 to 15 pounds per acre and when grown in mixtures, 6 to 8 pounds.

The average yield of timothy for hay for the whole United States was 1.16 tons per acre in 1926, ranging from 0.52 of a ton to as high as 2 tons under irrigation.

Although timothy is primarily a hay grass it probably is also the most important pasture grass used in short time pasture seedings. (703) (704)

835. Harvesting. The harvesting of timothy and other hay grasses has been discussed earlier in the chapter on hay. (See Chapter XXV.)

836. Rotation. Timothy is grown by many farmers as part of a five-year rotation, being seeded with clover in wheat or oats. The first year of meadow the clover is the principal crop, while the second year timothy predominates. The yields of timothy the second and third years are highest and decline thereafter, though plants have been reported as living 15 years. On many farms the timothy is left down one or more years for pasture after providing a hay crop for one or two years.

837. Seed Production of Timothy. Timothy is normally cross-pollinated by the wind but the flowers are not entirely self-sterile. The seeding habit of timothy is probably one of the most important factors in giving timothy the important place which it holds among our hay and pasture grasses. It is a sure seeder, with good yields, and the seed crop can be handled easily. The grass when ripe is cut with a grain binder and put into small shocks, where it is allowed to cure for a week or more. Threshing is done with the ordinary grain separator with special sieves. Yields of seed average 5 or 6 bushels per acre. Yields as high as 12 bushels have been reported. The chief producing states are Iowa, Missouri, Minnesota, Illinois, Ohio, South Dakota, and Wisconsin.

KENTUCKY BLUEGRASS

Kentucky bluegrass (*Poa pratensis*)[3] is commonly referred to as bluegrass or June grass. Although not native to North America it is by far the most important pasture and lawn grass north of the cotton belt. Bluegrass is native to practically all of Europe and the northern half of Asia. **(671) (672)**

838. Description and Adaptation. Kentucky bluegrass is a perennial and spreads both by seeds and by creeping underground stems. The panicles are spreading and are purplish in color. The stems are rather fine and cylindrical. Kentucky bluegrass blooms but once each season. When not in bloom it can be recognized by the leaves which are V-shaped in cross sections, and the tip of the leaf resembles the bow of a boat. Kentucky bluegrass is adapted to temperate regions of relatively high humidity. It is extremely resistant to cold. During the heat of mid-summer it languishes, often turning brown during the months of July and August but reviving again in the fall when rains and cool weather come. It does best on well-drained loams or clay soils rich in humus. The soil of the famous bluegrass region of Kentucky is of limestone origin. Bluegrass is not so well suited to wet soils as redtop and is not as well adapted to growing in the shade as either redtop or orchard grass. **(700) (701)**

839. Culture. Bluegrass comes on rather slowly after seeding and does not develop a sod until the second or third year. For this reason it is generally seeded with timothy and clover which furnish most of the pasturage the first two years. Seeded in mixture the rate of seeding may vary from 5 to 15 pounds per acre. Recommendations for a full seeding of bluegrass vary from 20 to 40 pounds per acre. When seeding lawns the use of 50 to 60 pounds per acre is usually recommended. The germination of the seed is very uncertain, much of the seed offered being of low quality. **(703)**

840. Feeding Value of the Crop. Kentucky bluegrass is very palatable to all classes of livestock, either as pasture or hay, but is seldom cut for hay, since the yield is too low to make this profitable. The hay is considered to be of good quality but not equal to timothy.

841. Seed Production. Kentucky bluegrass seed is harvested in Kentucky, Missouri, and Iowa, the chief method of harvesting being the use of stripping machines which pull the ripening seed heads from the standing plants in the field. The stripped seed is piled in narrow ricks or windrows to cure, turning frequently to prevent heating. Seed growers usually cure the seed out and then sell it in the rough to dealers equipped with special seed cleaning machinery. The usual time of harvesting is about the middle of June.

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[3] Piper, C. V.—"Important Cultivated Grasses." *U. S. Dept. Agr. Farmers' Bul. 1254.* 1922.

842. Canada Bluegrass. Canada bluegrass (*Poa compressa*) has culms which are more or less wiry and flattened, with more narrow and blunt panicles than Kentucky bluegrass. The plant is bluish green in color. This plant spreads by numerous creeping rhizomes, which are not tufted at the end as in the case of Kentucky bluegrass. The seed so resembles Kentucky bluegrass that the average person cannot distinguish the two. The seed of Canada bluegrass is usually cheaper than the seed of Kentucky bluegrass and is used to adulterate Kentucky bluegrass. It is cheaper because of the fact that it can be cut and handled much the same as hay, cocked, and then threshed later with an ordinary grain separator with special screens. Canada bluegrass is important because of the fact that it is well adapted to soils low in fertility where the growth of the Kentucky bluegrass is unsatisfactory. Climatically, Canada bluegrass is adapted to about the same regions as Kentucky bluegrass. It is much inferior to Kentucky bluegrass either for pasture or for lawns, as it is much less leafy, with few basal leaves and the culm leaves short and erect.

REDTOP

Redtop (*Agrostis alba*) is sometimes known as Herd's grass, marsh bent, and southern bent grass. It is a perennial which succeeds fairly well wherever bluegrass can be grown and thrives in warmer and drier sections of the country and on less fertile and on more poorly drained soils than the bluegrass. It is particularly well adapted to moist or wet soils and it will even grow under water for a time. The redtop plant has erect culms varying from one to four feet in height. The plant grows in tufts and spreads by shallow root stocks. The panicles vary from greenish to purple or brown in color. **(700)**

843. Uses and Culture. Redtop is generally recommended for hay and pasture uses on low, wet land. It is seldom grown alone either for hay or for pasture, being seeded in mixture with other grasses, chiefly timothy. **(703)**

Redtop seed are very small, having as high as 4,000,000 seed per pound. Eight to 12 pounds of clean redtop seed per acre is recommended. In mixtures with timothy 4 to 6 pounds are used. The great bulk of the commercial redtop seed crop is produced in southern Illinois, where it is either stripped as Kentucky bluegrass is harvested or cut with a binder or mower, cured in stacks or shocks, and threshed with specially equipped separators.

Redtop is usually grown only under conditions where better grasses do not thrive, as it is relatively unpalatable, either for hay or pasture. (701)

ORCHARD GRASS

Orchard grass (*Dactylis glomerata*) is a perennial, native to Europe and in England is commonly called cocksfoot. It is a bunch grass, commonly growing two to four feet in height. The spikelets are borne in one-sided bunches at the end of the principal branches of a panicle.

844. Adaptation. Orchard grass does not stand cold as well as timothy, but it can be grown further south as it can stand a longer season of heat than timothy. Orchard grass is not particular with reference to the soil type but does best on clays and loams with a moderate amount of moisture. It is well suited to growing in shade, as for example in wooded pastures.

845. Uses. Orchard grass is a valuable hay grass, particularly in the southern edge of the corn and timothy belt; it is also used for pasture when grown in mixtures. It cannot compete with timothy in the corn belt. It is particularly noted for its ability to grow in shaded places, for its early growth in the spring of the year, and its quick recovery after being grazed off. (700) (701) (703)

Helm[4] states that orchard grass is the most valuable pasture, meadow, and seed crop for southern Missouri, and especially for the Ozark section.

846. Culture of the Crop. From 12 to 20 pounds of orchard grass seed are used per acre, with a somewhat thinner rate when the crop is grown for seed. The seed may be sown either in the fall or very early in the spring. In general, spring seeding is preferred.

It is important that orchard grass be cut by the time it has reached the full bloom stage, as it rapidly becomes woody and unpalatable if allowed to become more mature. This stage is reached considerably before timothy is ready to cut. Orchard grass seed is harvested with the grain binder and allowed to cure out in the shock and then threshed with an ordinary grain thresher with special riddles. The crop must be handled very carefully as the seed shatters easily. The principal states which produce orchard grass seed are Kentucky, Ohio, Indiana, and certain sections of Virginia.

SMOOTH BROME GRASS

Smooth brome grass (*Bromus inermis*)[5] is native to Europe, being grown chiefly in Hungary and Russia.

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[4] Helm, C. A.—"Growing Orchard Grass in South Missouri." *Mo. Agr. Expt. Sta. Circ. 130.* 1924.

[5] Piper, C. V.—"Cultivated Grasses of Secondary Importance." *U. S. Dept. Agr. Farmers' Bul. 1433.* 1925.

It is a perennial with numerous creeping root stalks and forms a dense, heavy sod. The stems grow from 2 to 3 feet in height, smooth and leafy, with the seed borne in open, spreading panicles which are from 4 to 6 inches long. The spikelets are about an inch long, brown or purplish in color with 8 to 10 flowers; seeds are somewhat flat with a very short awn, or no awn.

847. Adaptation. Brome grass is especially adapted to the Dakotas, and other regions of relatively low rainfall, with low or moderate temperatures. In the wild state it grows in dry, gravelly soils or even in pure sand. Brome endures the winter temperatures of the Northwest and extends well up into Canada. (700) (701) (703)

848. Use. Brome grass is valuable both as a hay and a pasture crop. The hay yields are good for two or three years, after which the yield falls off as the root growth becomes so dense as to result in a "sod-bound" condition. This may be remedied by a thorough disking or by shallow plowing. Brome grass is usually seeded in the spring at the rate of 10 to 15 pounds per acre. Brome grass may be cut for hay in the full bloom stage. Two cuttings are often obtained in a season. The yields of hay vary from 1 to 4 tons per acre.

Brome grass is one of the most palatable of all grasses. It begins to grow very early in the spring, comparing favorably with orchard grass in this respect. Brome pasture will stand much abuse due to the fact that it forms a good sod, but when seeded in mixture and close grazed it is soon crowded out by Kentucky bluegrass.

849. Seed Production. When the seeds are brown, brome grass is cut with an ordinary grain binder or with a header and threshed with an ordinary threshing machine. The yields range from 100 to 700 pounds of seed per acre with an average of around 300 pounds. Brome grass is sometimes difficult to eradicate in the Northwest, especially on rich, loamy soil.

Bermuda Grass

Bermuda grass (*Cynodon dactylon*) is a native to India and perhaps other parts of the old world. It is the most palatable and most valuable pasture grass grown in the southern states, where it is also used extensively in mixture for hay and as a lawn grass. It is called wire grass and devil's grass in certain sections where it is troublesome as a weed. (700) (703)

850. Description of the Plant.[6] Bermuda grass is a perennial which spreads by runners or rootstocks. In certain sections it also spreads by seed. Single plants have been known to spread over an area 20 feet in diameter in one season. Runners lie flat on the ground, taking root at each node. In thick stands the culms of Bermuda grass are 6 to 12 inches in length and stand erect and may be cut for hay. The flowers are borne in slender, spreading spikes one-half to one inch long, four to six spikes being attached at one point, in an umbel.

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[6] Tracy, S. M.—"Bermuda Grass." *U. S. Dept. Agr. Farmers' Bul. 814*. 1917.

851. Adaptation. Bermuda grass requires warm weather during the growing season and can stand intense heat without injury. It cannot withstand low temperatures. While it grows best with a reasonable amount of water, it does well on soils which are not thoroughly drained. It withstands drouth very well, but makes very little growth during the dry weather. It is not a shade-loving plant. Bermuda grass grows well on most types of soil. It is confined largely to the cotton belt, including southern Arizona, New Mexico, and California. (672)

852. Culture of the Crop. Bermuda grass is ordinarily planted early in the spring by means of root cuttings. Fresh sod from an old Bermuda grass field is spaded or plowed up, chopped, and distributed over the field, or placed in furrows by hand in small pieces and covered with the foot. Bermuda grass will quickly cover the ground when planted in this manner. Bermuda grass, while generally propagated by sod, may be propagated by seed. The plant seeds freely in southern California, Arizona, and New Mexico. Five pounds of good seed, per acre, seeded shallow, is sufficient.

853. Bermuda Grass for Pasture. This grass is used for pasture for all types of livestock. It is well liked by hogs but they will root up the Bermuda grass pastures to get the root stocks. Bermuda grass is included in most of the permanent pasture mixtures seeded in the South and under most conditions it will crowd out other grasses. On sandy land along the coast, carpet grass is recommended to be seeded in mixture with Bermuda grass. Under favorable conditions, Bermuda grass is reported as supporting as high as three or four animal units per acre, though on average soils about one animal unit to the acre is the normal carrying capacity.

854. Bermuda Grass for Hay. Yields of Bermuda hay vary widely. The average yield would probably be in the neighborhood of 1½ tons per acre, though as many as 5 tons per acre have been reported. If to be cut for hay, the sod needs to be torn up at times as it will become sod-bound. This is done either by plowing or by disking the field.

Bermuda grass makes an excellent grass for lawns for the South. It remains green during the summer even in dry weather but becomes brown with the first severe frost in the fall. Bermuda grass is the best plant known for holding soil which is inclined to erode.

855. Eradication.[7] Bermuda grass is sometimes difficult to eradicate. The ordinary methods of eradicating grasses by cultivation or deep plowing at any season of the year are not successful with Bermuda grass. Shallow plowing in the northern part of the cotton belt, exposing the roots so that they will be frozen, kills Bermuda grass fairly well. The grass also can be smothered out. To do this the land is plowed in September and planted with winter oats or rye, and this crop followed by another fairly rank growing crop in the midsummer following. Very little Bermuda grass is left after these two crops are off.

856. Other Cultivated Grasses. There are a considerable number of other grasses which are of importance in some sections of the country. Brief information on the characteristics of these grasses and their adaptation can be secured from the *U. S. Dept. of Agr. Farmers' Bulletins 1254* and *1433,* already referred to in this chapter.

STUDY QUESTIONS ON CHAPTER XXXII

1. Prepare a chart outline, from which a person not familiar with the grasses might be expected to identify any one of the more important ones.
2. What are the factors which have been most important in making timothy the most widely grown grass hay plant in the United States?
3. What is meant by the "first bloom" and the "second bloom" of timothy?
4. Give instructions for harvesting a crop of timothy for hay. A seed crop.
5. What factors are most largely responsible for the fact that Kentucky bluegrass is used so generally for pasture purposes in the United States?
6. Give such instructions as are necessary to secure a good bluegrass sod.
7. Describe the methods of harvesting and cutting Kentucky bluegrass seed.
8. Distinguish between the Kentucky and the Canada bluegrass. Under what conditions would the Canada bluegrass be superior?
9. Under what conditions would redtop be recommended? Give instructions for seeding the crop.
10. For what conditions might orchard grass be recommended as superior to any other grass available? Give instructions for putting in a crop which is to be harvested for seed.
11. Under what conditions might the smooth brome grass be expected to be superior to other grasses available? Give instructions for seeding and for use as a hay crop. As a pasture crop.
12. Under what conditions would Bermuda grass be recommended? Give instructions for seeding the crop. How would you eradicate a Bermuda sod?

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[7] Hansen, A. A.—"Eradication of Bermuda Grass." *U. S. Dept. Agr. Farmers' Bul. 945.* 1918.

APPLICATION ASSIGNMENTS ON CHAPTER XXXII

1. You plan to put down 20 acres in permanent pasture on your corn belt farm. What will you seed and how will you make the seeding?
2. You have a field of Kentucky bluegrass with a heavy setting of seed. You are considering harvesting the crop for seed. What will be the determining factors? How would the seed crop be handled?
3. A permanent pasture is desired on a rich black loam in northern Mississippi. You will plan to graze the pasture heavily. What will you want to use? Give instructions for establishing the pasture.
4. On a corn belt farm you wish to establish a permanent pasture. A part of the field is a steep hillside and the rest is poorly drained. What will you plan to seed on each part of the field and how will you make the seeding?
5. On a poor hillside in your pasture the Kentucky bluegrass has been crowded out by a weedy growth. What can you seed here which may be expected to maintain itself? Explain.
6. A timbered pasture is seeded to Kentucky bluegrass but is not giving satisfactory returns. What grass might profitably be seeded and how would you make the seeding?
7. A farmer in north central Illinois has been seeding clover alone but has failed to get a crop. He has decided to seed some grass in mixture with the clover. What grass would you recommend? What would you recommend under similar conditions in southern Kentucky?
8. A hay grass crop is desired on a farm in east central North Dakota. What will you recommend? Explain.
9. An old hay meadow is not making enough growth to cut for hay in spite of the fact that the soil is rich. What is the trouble? Suggest a remedy.

CHAPTER XXXIII

THE ANNUAL GRASS CROPS

While there are a number of annual grasses which have some value in particular regions, there are only two annual grass crops which have not been covered in other discussions and which are of such value as to justify their inclusion here, Sudan grass and the millets.

SUDAN GRASS

857. History and Description. Sudan grass (*Andropogon sorghum sudanesis*), an annual hay plant belonging to the sorghum family, grows to a height of 4 to 8 feet. It was introduced from Sudan, Africa, in 1909 through the efforts of C. V. Piper and has become easily the most important annual hay grass in the United States. Sudan grass is very similar in appearance and growth to *Sorghum halepense*, a perennial with vigorous root stalks, represented in this country by Johnson grass. While the plant makes a coarse growth the leaves are rather numerous and soft. The seed are borne in open panicles. The plant produces numerous tillers and the tillers may branch.

FIG. 148.—In a good soil with abundant moisture Sudan grass will make a growth of from four to eight feet. *Under what conditions is Sudan grass recommended for hay? For pasture? What are the strong points of this grass? What are its shortcomings?*

858. Adaptation of Sudan Grass. Sudan grass prefers a fertile soil in good tilth but makes better yields on poor soils than most hay crops. Cold, wet soils are particularly unsuited to Sudan grass. It is as resistant to acid soils as the ordinary cereals but many crops are more resistant to alkali soils than is Sudan. Climatically, Sudan grass grows best in a warm climate with a well-distributed rainfall. It is not as cold-resistant as corn in its early stages of growth and does not do well in extreme northern latitudes or high altitudes. Like the other sorghums, Sudan is quite drouth-resistant. It has the ability of going into a semi-dormant state during a period of drouth and then reviving when moisture becomes available.

859. Uses of the Crop. With summer temperatures Sudan grass makes a rapid growth and often can be seeded to advantage as a catch crop or an emergency hay crop after some other crop has failed. Due to the fact that it makes a large growth of forage it is used as an emergency pasture crop or as a temporary pasture to tide over periods of the summer when other pastures are relatively non-productive. As a hay crop, Sudan has replaced a large part of the millet acreage in the Great Plains and in the southwest as well as in other parts of the country. It may be cut and fed green as a soiling crop and it has been utilized to a limited extent for silage purposes although for this latter purpose sorghum seems to have greater value.

860. Time of Seeding Sudan Grass. Getty[1] reports a test in western Kansas where Sudan grass was seeded April 15, May 1, May 15, June 1, June 15, July 1, July 15, and August 1. The yields as an average for six years were 0.37, 1.51, 18.84, 1.84, 1.87, 1.61, 1.30, and 0.59 tons per acre, respectively.

Vinall and Getty[2] report experiments in various parts of the United States comparing the yields of Sudan grass when seeded at intervals from April 1 to July 15, Table *860a*.

860a. Date of seeding Sudan grass and yield, tons per acre. Summary.

LOCATION OF TEST	YIELDS OF CURED HAY (PER ACRE) FROM PLANTINGS MADE ON							
	Apr. 1	Apr. 15	May 1	May 15	June 1	June 15	July 1	July 15
Southern section Average	3.21	3.18	2.83	2.76	2.69	2.32	1.83	1.33
Middle section Average	1.14	1.45	2.15	2.27	2.28	2.20	1.66	1.35
Northern section Average			3.75	3.71	3.82	3.63		

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[1] Getty, R. E.—"Forage Crops in Western Kansas." *Kans. Agr. Expt. Sta. Bul. 225*, p. 32. 1921.

[2] Vinall, H. N., and Getty, R. E.—"Sudan Grass and Related Plants." *U. S. Dept. Agr. Dept. Bul. 981*, p. 28. 1921.

Fig. 149.—Plots of Sudan grass seeded at weekly intervals at the Iowa Station, from May 3 to June 26, gave average yields for a four-year period of from 4.26 tons of hay per acre to 1.32 tons.

Hughes and Wilkins[3] report the yields of cured hay secured through a six-year period from seedings of Sudan made at weekly intervals from in early May until in late July, Table *860b*.

860b. Effect of time of seeding on the yield of Sudan hay. Iowa.

Date of Seeding	Yield (Tons per Acre)						Ave. 20-21 22-23
	1919	1920	1921	1922	1923	1924	
May 3	2.48	3.63	5.20	4.68	4.33	3.32	4.46
May 10	3.30	3.88	5.29	3.60	4.61	...	4.35
May 17	1.65	3.54	4.91	4.37	4.66	3.55	4.37
May 24	3.71	3.48	4.91	4.14	4.81	...	4.34
May 31	3.25	3.67	4.04	5.43	4.39	2.66	4.38
June 7	2.48	2.04	4.51	5.15	4.34	...	4.01
June 14	3.30	2.35	3.34	4.15	4.84	2.97	3.58
June 21	3.30	2.50	1.71	3.30	4.74	...	3.06
June 28	4.95	1.25	1.55	3.15	4.32	3.38	2.57
July 5	...	2.50	1.75	2.46	3.76	...	2.62
July 12	...	1.49	1.65	2.21	3.01	1.69	2.09
July 19	...	1.49	1.74	1.82	2.02	...	1.77
July 26	...	.86	1.79	1.45	1.17	1.00	1.32

861. Rate of Seeding. Vinall and Getty report extensive experiments in various parts of the country from seeding Sudan grass at the rate of 10, 15, 20, 25, 30, 35, and 40 pounds per acre.

861a. Rate of seeding Sudan for hay; yields in tons per acre. Summary.

Location of Test	Hay Yields When Seeded at Following Rates per Acre				
	10 Lb.	15 Lb.	20 Lb.	25 to 30 Lb.	35 to 40 Lb.
Humid regions					
Average		2.91	2.95	3.02	2.87
Dry regions (not irrigated)					
Average		3.37	3.32	3.19	3.22
Dry regions (irrigated)					
Average	5.34	4.88	4.98	4.46	4.46

Hughes and Wilkins report a test covering a period of five years, giving the yields of hay, straw, and seed for 10, 15, 20, and 25 pound rates of seeding, Table *861b*.

Getty,[4] at the Kansas Station, compared different rates of seeding, —from 4 to 35 pounds per acre. He states that the results vary little for the various rates of seeding and methods of planting, the lowest

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[3] Hughes, H. D., and Wilkins, F. S.—"Sudan Grass." *Iowa Agr. Expt. Sta. Bul. 233.* 1926.

[4] Getty, R. E.—"Forage Crops in Western Kansas." *Kans. Agr. Expt. Sta. Bul. 225*, pp. 33-34. 1921.

861b. Rate of seeding Sudan. Iowa.

	RATE PER ACRE			
	10	15	20	25
Hay	3.36 tons	3.45 tons	3.62 tons	3.51 tons
Straw	2.17 tons	2.20 tons	2.04 tons	2.25 tons
Seed	541 lbs.	544 lbs.	534 lbs.	622 lbs.

average yield being only 10 per cent less than the highest average and in no year has any rate or method shown outstanding superiority. The yields seemed to depend chiefly upon the season. For Kansas conditions he recommended from 15 to 20 pounds per acre when seeded in drill rows 6 to 8 inches apart, and 3 to 4 pounds when the rows are 3 to 3½ feet apart.

862. Method of Seeding. Madson and Kennedy seeded in 18-inch rows, in 36-inch rows and in solid drills, both with irrigation, and with dry land conditions. They state that when the supply of moisture is fairly abundant the highest production can be obtained by planting in rather narrow rows and that under drier conditions the yields are equally as good as with wider rows. On irrigated land the method of seeding is not important.

Hughes and Wilkins report a yield of 3.48 tons of hay per acre when broadcast and 3.46 when drilled. The yields of seed were 540 and 602 pounds per acre, respectively. When seeded at the rate of 10 pounds per acre in 8-inch rows, in 16-inch rows and in 32-inch rows, the tons of hay per acre were 3.41, 3.50, and 3.73 tons, respectively.

Vinall and Getty summarized data from various parts of the United States showing the effect of close drilling or broadcasting, compared with 18- to 24-inch rows and with 34- to 44-inch rows, Table *862a*.

862a. Method of seeding Sudan grass for hay. Summary.

LOCATION OF TEST	YIELDS PER ACRE; TONS		
	Close Drilled or Broadcast	18- to 24-Inch Rows	34- to 44-Inch Rows
Humid regions Average	3.42	3.80	3.61
Dry regions (not irrigated) Average	1.81	1.95	1.72
Dry regions (irrigated) Average	4.93	5.24	4.64

863. Time to Cut Sudan Grass for Hay. Vinall and Getty state that the local conditions determine the time of cutting. The hay made at about the time the grass heads is somewhat more palatable than later cuttings.

Hughes and Wilkins[5] state that the time of cutting is relatively unimportant and may be done from the time the grass begins to head until it is in the hard dough stage. If cut when in the period of heading two crops can be had in most sections of the country. A greater total yield can be secured from two cuttings than from one, but the crop is more difficult to cure because of the higher moisture content.

864. The Seed Crop. For seed, the crop is cut when three-fourths of the seed is ripe and hard. The seed crop of Sudan grass is usually harvested with a grain binder and cured out in the shock and threshed with the grain separator.

Williams[6] at Ohio reports yields of seed ranging from 10 to 30 bushels per acre.

Hughes and Wilkins report the average yield of seed at the Iowa Experiment Station as a six-year average as 574 pounds per acre, while the highest yield secured was 1372 pounds. Yields as high as 2000 pounds have been reported.

Vinall and Getty[7] report the average yield of seed per acre at a large number of stations in the United States, when broadcast or drilled, when in cultivated rows 18 to 24 inches, and when in rows 36 to 44 inches apart. These are pooled under humid sections, dry regions not irrigated, and dry regions irrigated, Table *864a*.

864a. Yield of Sudan seed. Summary.

LOCATION OF TEST	YIELDS OF SEED PER ACRE; POUNDS		
	Broadcast or in Close Drills	18 to 24 Inches Apart	36 to 44 Inches Apart
Humid regions Average	328	417	354
Dry regions (not irrigated) Average	206	285	271
Dry regions (irrigated) Average	1123	966	905

In growing a seed crop care must be taken that other sorghums are not grown near the Sudan grass as it has been found that Sudan grass crosses very freely with sorghum.

865. Feeding Value of Sudan Hay. Vinall and Getty have summarized the information on the feeding value of Sudan grass hay,

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[5] Hughes, H. D., and Wilkins, F. S.—"Sudan Grass." *Iowa Agr. Expt. Sta. Bul. 233*. 1926.

[6] Williams, C. G.—"Sudan Grass as an Ohio Crop." *Ohio Agr. Expt. Sta. Mo. Bul.* Vol. 4, No. 5, p. 142. May, 1919.

[7] Vinall, H. N., and Getty, R. E.—"Sudan Grass and Related Plants." *U. S. Dept. Agr. Dept. Bul. 981*, p. 58. 1921.

They found that it is very similar to that of Johnson grass, timothy, and millet. The digestibility ranks somewhat above timothy but below millet. In humid regions Sudan grass has a lower percentage of protein and ash than when grown in the semi-arid regions. It is an effective roughage for work stock, dairy cows and stock cattle. (666) (667) (669)

866. Sudan Grass for Pasture. A large number of tests have shown Sudan grass to have a high value for summer pasture. Characteristic of the sorghum family to which it belongs there is some, though slight, danger of prussic acid poisoning. Thompson[8] reports a test at Garden City, Kansas, station in which an acre of Sudan grass provided 125 days of pasture for one animal. The milk records of the dairy herd showed that the milk flow of the cows increased an average 3.2 pounds daily per head each time they were turned upon the Sudan grass pasture as compared with the yield when they were grazed upon a good native pasture, containing both buffalo and bunch grasses.

Sudan is not suitable for a full season pasture as it cannot be seeded until late in the spring, makes a rather slow growth in the early part of the season, and is gone with the first frost. It makes a rapid growth and large production per acre in midsummer.

867. Sudan Grass in Mixtures. Hughes and Wilkins report that Sudan grass and soybeans grow successfully when mixed. The mixture does not yield as much hay as Sudan grass alone, but the feeding value should be greater.

Vinall and Getty summarize experiments in various sections of the country comparing Sudan grass and soybeans or Sudan grass and cowpeas with Sudan grass alone. The Sudan grass and soybean mixture produced 2.96 tons per acre as an average of all trials, Sudan grass and cowpeas 2.93 tons, and Sudan grass alone, 2.67 tons. They conclude that mixed plantings of Sudan grass and a legume such as cowpeas or soybeans is profitable only in the more humid regions where the legumes and Sudan grass both grow successfully.

MILLET

868. Types of Millet. There are four major types of millet grown and used for forage purposes,—foxtail millet (*Setaria italica*), proso (*Panicum miliaceum*), barnyard millet or Japan millet (*Echinochloa frumentacea*), and pearl millet (*Pennisetum glaucum*). Foxtail millet is sometimes called Italian millet, while proso is referred to as broom corn millet or hog millet. Barnyard millet is referred to as

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[8] Thompson, G. E.—"Sudan Grass in Kansas." *Kans. Agr. Expt. Sta. Bul. 212.* 1916.

Japanese millet and million-dollar grass. Pearl millet is called Penicillaria, cat-tail millet, and Egyptian millet. There are a number of other minor species.

869. Foxtail Millets. Foxtail millets are annual grasses with slender, erect or ascending stems, occasionally branching, and growing from 2 to 4 feet under cultivation. The leaves are broad and flat. The seed are borne in rather dense cylindrical spikes, which have persistent bristles attached to the rachis at the base of each spikelet. They are enclosed in a thin papery chaff or outer glumes which are largely removed in threshing, leaving the small convex, oval, or elliptical seed free. The grain or kernel of this seed is enclosed in persistent glumes or hulls. Foxtail millet seed differs in appearance with the variety. Most of the foxtail millets have pale yellow or straw-colored seed. Siberian millet has reddish orange-colored seed. The Hungarian has a mixture of brown and yellow seed. In the common millet the seed is distributed rather evenly over the head, while in German millet the seed is arranged in distinct lobes on the spike.

Vinall [9] compares the plant characteristics of the different varieties of foxtail millet as shown in Table *869a.*

869a. Contrasting plant characters of the principal varieties of foxtail millet. Vinall.

VARIETY	AVERAGE PERIOD OF GROWTH —DAYS	SIZE OF STEM	SIZE OF HEAD [a]	CHARACTER OF HEAD	LENGTH OF BRISTLES [b]	COLOR OF BRISTLES	OUTLINE OF SEED	COLOR OF SEED
Common	69	Slender	Medium	Not lobed	Long	Pale yellow	Oval to elliptical	Pale yellow
German	87	Stout	Large	Distinctly lobed	Long	Green to purple	Round	Pale yellow
Golden Wonder		Stout	Large	Distinctly lobed	Short	Pale yellow	Round	Pale yellow
Gold Mine	69	Medium	Medium	Not lobed	Long	Pale yellow	Oval to elliptical	Pale yellow
Hungarian	69	Slender	Small	Not lobed	Long	Purple	Oval to elliptical	(c)
Siberian	72	Medium	Medium	Not lobed	.....	Purple	Oval to elliptical	Pale orange
Kursk	64	Slender	Small	Not lobed	Long	Purple	Oval to elliptical	Pale orange
Turkestan	93	Stout	Large	Slightly lobed	Long	Purple	Oval to elliptical	Pale orange

[a] Small, indicates heads 4½ inches long and ½ to ⅝ inch in diameter.
Medium, from 4½ to 6 inches long and ⅝ to ¾ of an inch in diameter.
Large, 6 to 9 inches long and 1 to 1¼ inches in diameter.

[b] Long, indicates bristles longer than the spikelets making the head appear bristly. Short, indicates bristles shorter or about equal in length to the spikelets and making the head appear smooth.

[c] Seed pale yellow and some purple or black.

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[9] Vinall, H. N.—"Foxtail Millets: Its Culture and Utilization in the United States." *U. S. Dept. Agr. Farmers' Bul. 793.* 1917.

870. Proso or Hog Millet.[10] Proso or barnyard millet is distinguished from the foxtail millet in that the seed heads are open with branching panicles like oats. The plant has coarse, hollow, woody stems 12 to 48 inches in height. Proso may be considered strictly a grain crop as it is not ordinarily grown for hay, since the hay is harsh, coarse, unpalatable and low in nutritive value. This millet is grown to some extent in the northern Great Plains area.

871. Japanese or Barnyard Millet. Japan millet is a coarse growing millet with thick stems and is closely related to the weed called barnyard grass. The stems grow erect and the seed are partially awned. The seed head is a dense mass of short racemes with the seed usually enclosed in a gray hull.

872. Pearl Millet. Pearl millet or cat-tail millet is an erect, tall annual, usually growing to a height of 5 to 8 feet, but on rich soil it has attained a height of 15 to 16 feet. The stems are woody with a dry pith and without sugar content. The stems become hard and pithy as growth progresses and the crop is reported to have little value for forage unless it is cut before it is over three or four feet high. Of all millets this is regarded as the lowest in value.

873. Yield of Millets Compared. Numerous comparisons between the various types of millet with some of the other standard crops have been made in various parts of the United States. Vinall[11] reports comparisons of foxtail millet, proso and Sudan in different parts of the country, Table *873a*.

873a. Yields of foxtail millets compared with those of proso and Sudan grass. Vinall.

LOCALITY	LENGTH OF TEST YEARS	HAY PER ACRE (TONS)							
		FOXTAIL MILLETS						PROSO	SUDAN GRASS
		Common	German	Kursk	Gold Mine	Hungarian	Turkestan		
Great Plains:									
Northern	5	1.66	1.56	1.79	1.36	1.62	1.73	1.38	2.19
Central	4	1.71	2.76	2.04	2.30	1.88	2.00	1.27	3.20
Southern	5	....	2.12	1.27	1.62	1.37	2.44	...	3.74
Northern Mississippi Valley ...	7	1.80	2.15	2.16	...	2.05	...	2.04	3.38
Northeastern corn belt	7	2.55	3.72	...	...	2.80	...	2.62	3.20
Southeastern states	4	...	3.25	...	...	...	...	...	3.45

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[10] Martin, John H.—"Proso or Hog Millet." *U. S. Dept. Agr. Farmers' Bul. 1162.* 1920.

[11] Vinall, H. N.—"Foxtail Millet: Its Culture and Utilization in the United States." *U. S. Dept. Agr. Farmers' Bul. 798.* 1917.

Brown[12] reports a comparison of hay yields (15 per cent moisture) of different annual forages in Connecticut, in which the yield of Japanese millet was given a value of 100. As a three-year average the yield of the best variety of soybeans was 81; the yield of Hungarian millet, 72; Sudan grass, 72; Siberian millet, 83; and golden millet (German millet), 62.

Kiesselbach and Anderson[13] report the average annual yields secured from a number of annual hay crops for a four-year period as follows: sweet sorghum varieties, 5 tons per acre; grain sorghums, 4.69 tons; Sudan grass, 3.25; common millet, 3.50; German millet, 3.47; Hungarian millet, 2.71, and Siberian millet, 2.63. Proso or hog millet averaged 1.36; Japanese or barnyard millet, 2.84 and pearl or cat-tail millet 3.95.

Megee[14] reports comparisons of air-dry hay at East Lansing as a three-year average. Sudan grass produced 3.33 tons per acre; German millet, 3.25; Japanese or barnyard millet, 3.22; soybeans, 2.67; Hungarian millet, 2.48; common millet, 1.94; oats and vetch, 1.99; and oats and peas, 1.78.

874. Feeding Value and Palatability of Millet. The digestible proteins, carbohydrates and fat in 100 pounds of dry matter of timothy, millet, and Sudan grass hay was determined by Gaessler and McCandlish.[15]

874a. Digestible protein, carbohydrates, and fats in 100 pounds of dry matter. Iowa.

CONSTITUENT	TIMOTHY HAY, LBS.	MILLET HAY, LBS.	SUDAN GRASS HAY, LBS.
Protein	3.4	5.8	3.6
Carbohydrates	48.4	53.6	58.3
Fat	1.4	2.1	1.0
Total digestible nutrients	54.0	64.2	64.2

Vinall[16] states that it is the opinion among feeders that millet hay is somewhat more effective than prairie hay but inferior to timothy and some of the tame grasses as a roughage hay for growing stock, especially cattle and sheep. It is not as palatable and is decidedly injurious to horses when fed continuously.

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[12] Brown, B. A.—"Summer Annuals for Hay in Connecticut." *Conn. [Storrs] Agr. Expt. Sta. Bul. 120.* 1924.

[13] Kiesselbach, T. A., and Anderson, Arthur—"Annual Forage Crops." *Nebr. Agr. Expt. Sta. Bul. 206.* 1925.

[14] Megee, C. R.—"Emergency Hay and Pasture Crops." *Mich. Agr. Expt. Sta. Spec. Bul. 150.* 1926.

[15] Gaessler, W. G., and McCandlish, A. C.—"Composition and Digestibility of Sudan Grass Hay." *Jour. Agr. Res.* Vol. XIV, No. 4, p. 184. July 22, 1918.

[16] Vinall, H. N.—"Foxtail Millet: Its Culture and Utilization in the United States." *U. S. Dept. Agr. Farmers' Bul. 793.* 1917.

875. Culture of the Crop. The millets are usually sown broadcast in the spring after the soil is thoroughly warmed up, though they may be seeded as an emergency hay crop in midsummer. The rate of seeding varies from 15 to 40 pounds per acre. The lower rate is advised for seed production with heavier seeding for the best quality and yields of hay. The crop is sometimes seeded in rows for seed production, especially in the drier sections of the country.

876. Harvest. Hay for general use is best cut shortly after blooming. Millet hay cures rather easily, particularly the foxtail millets.

Millet for seed is cut with the grain binder and placed in shocks and cured out much the same as small grain. It is threshed with the ordinary threshing machine with screens adapted to the small seed.

877. Yields of Millet Seed. Hume and Champlin[17] give some data on yields of millet seed. The yields ranged from 1.4 to 54.2 bushels per acre. The average yield of the foxtail varieties over a period of four years was 19.6 bushels per acre, and of the proso varieties, over a period varying from four to seven years, 16.4 bushels per acre. The legal weight per bushel of millet is 50 pounds.

Minnesota[18] reports a two-year comparison of Kursk, Red Turghai, and Japanese millet. As an average the Kursk produced 23.40 bushels per acre; Red Turghai, 21.53 bushels; and Japanese, 15.98 bushels.

STUDY QUESTIONS ON CHAPTER XXXIII

1. Under what conditions would you advise the use of Sudan grass? Explain.
2. Give instructions for planting a crop of Sudan grass in the central corn belt.
3. Give instructions for harvesting a crop of Sudan grass for hay. For seed.
4. Why has the acreage of millet not increased in proportion to other crops?
5. Distinguish the types of millet, giving the conditions under which each might be used to advantage.
6. How do the different millets compare in yielding ability? In feed value? How do they compare with other annual grass crops in feeding value? Under what conditions would you seed millet?
7. Give instructions for growing a crop of millet for hay. For seed.

APPLICATION ASSIGNMENTS ON CHAPTER XXXIII

1. Your corn was hailed out on July 5 and you wish to put in a hay crop. The soil is very rich. What crop will you grow? Why?

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[17] Hume, A. N., and Champlin, Manley—"Trials with Millets and Sorghums for Grain and Hay, in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 135*. 1912.

[18] Arny, A. C., and McGinnis, F. W.—"Field Crop Variety Trials on the Coon Creek Peat Experimental Fields, 1919-1925." *Minn. Agr. Expt. Sta. Bul. 228*. 1926.

2. You grew a large crop of Sudan grass last year. You plowed this land in the spring and planted to corn. The corn did not do as well as you thought it should, considering the soil. Explain.
3. On August 1st your Sudan grass is heading out. You have time to cut it now. You are thinking you might get two crops. What factors will influence your decision? What will you do?
4. A field is to be planted to millet for a seed crop. What type of millet will you grow? How will you harvest the crop?

CHAPTER XXXIV

ROOTS AND OTHER SUCCULENT FORAGE

Most of the root crops have been developed and used primarily as human food, but in northern Europe root crops are grown extensively as forage for livestock. In 1918 root crops occupied 9.7 per cent of the total acreage under crops and grass in Denmark, and 5.4 per cent of the total acreage in Great Britain. They are not important in the United States but are grown to a limited extent as forage in Michigan, Wisconsin, California, Washington, New York, and Minnesota, and to a much greater extent in parts of Canada. In general, root crops will not be grown extensively in regions where large yields of corn and sorghums can be obtained with a much smaller expenditure of labor.

878. Mangels. Mangels belong to the botanical species *Beta vulgaris* as do the sugar beets. The sugar beet has been discussed. (Chap. XXIII.) The life history of the mangel is very similar to that of the sugar beet. Mangels vary rather widely in the color, size, and shape of the root. They are classed as long, half-long, tankard, oval, or globe and vary in color from white to pink, red, orange, gold, purple, or black.

McRostie[1] reports a comparison of 147 lots of mangels, representing practically every variety offered for sale in Canada. He states that the tankard and globe types are essentially shallow soil types, while the ovate, intermediate, and half long are suitable for average soils. The mangel reaches its full development on deep, friable loam. In these comparisons the yield of the beets ranged from 4.1 tons of dry matter per acre in the case of the Giant White Feeding Beet and the Mammoth Giant Yellow to 2.25 tons per acre for the Golden Tankard and Giant Yellow Intermediate. The yields as harvested varied from 23 tons per acre in the case of the Golden Tankard to 46.2 tons in the case of the Yellow Eckendorfer.

879. Various Root Crops Compared. Hume[2] reports a two-year comparison in South Dakota, in which the best variety of sugar beets yielded 9.95 tons of roots per acre; mangels, 11.97 tons; carrots, 7.54 tons; turnips, 8.24 tons; and rutabagas, 13.48 tons.

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[1] McRostie, G. P.—"Mangels." *Canada Expt. Farms. Div. Forage Plants Rpt.*, pp. 19-22. 1926.

[2] Hume, A. N.—"Root Crop Culture in South Dakota." *S. Dak. Agr. Expt. Sta. Bul. 180.* 1918.

In root comparisons at the Superior station, Wisconsin,[3] the average yield of rutabagas was 13.75 tons per acre; carrots, 7.01; feeding sugar beets, 6.96 tons; red mangels, 5.88; Golden Tankard mangels, 4.84; and Yellow Aberdeen turnip, 12.1.

Knight[4] reports the three-year average yield of various root crops in Nevada. The Ideal mangel produced 15.73 tons per acre; the Mammoth Long Red mangel, 13.84 tons; the Golden Tankard, 13.30 tons; the Giant Feeding mangel, 12.83 tons; and sugar beets, 12.06 tons per acre. The sugar content of the plants varied from 4.5 per cent for the Ideal mangel to 19.5 per cent for the sugar beets, all the mangels having between 4.5 and 7.3 per cent of sugar.

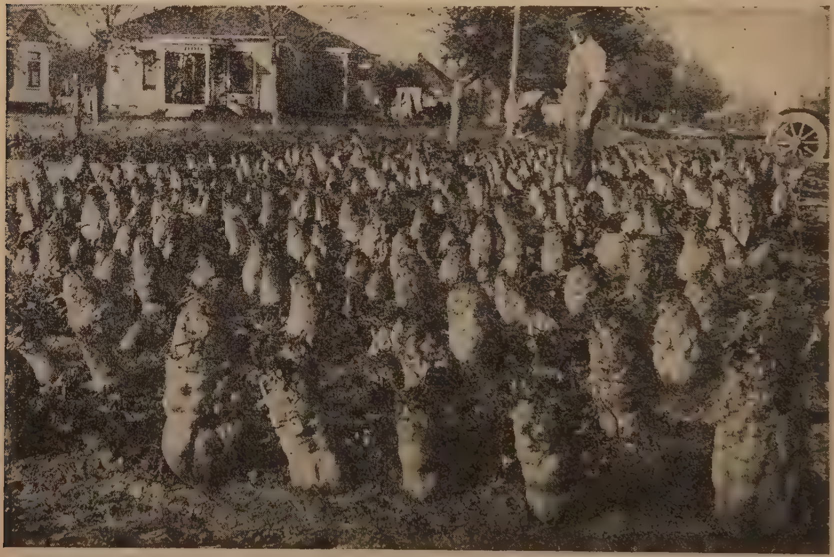

FIG. 150.—A planting of mangles at Shenandoah, Iowa, in the heart of the corn belt. Mangels may produce ten to twenty tons per acre or even more. *Under what conditions can mangles replace such a succulent feed as corn silage?*

Arny and McGinnis[5] report that on an 18 per cent water basis, which makes the root crop somewhat comparable to hay, sugar beets produced 3.05 tons per acre; rutabagas, 2.01 tons; Yellow Globe mangels, 1.85 tons; Mammoth Long Red mangels, 1.87 tons; and carrots, 1.76 tons. They state that the dry matter in roots is similar in feeding value to the dry matter in grain, and that owing to its higher digestibility it is more valuable than like weights of forage of the same moisture content.

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[3] Delwiche, E. J.—"Profitable Root Crops." *Wis. Agr. Expt. Sta. Bul. 330.* 1921.

[4] Knight, C. S.—"Forage and Root Crops." *Nev. Agr. Expt. Sta. Bul. 86.* 1917.

[5] Arny, A. C., and McGinnis, F. W.—"Field Crop Variety Trials at the Coon Creek Peat EExperimental Fields, 1919 to 1925." *Minn. Agr. Expt. Sta. Bul. 228.* 1926.

The Michigan Station[6] reports average yields of various root crops for a three-year period as shown in Table *879a*. They state that Michigan farmers prefer the Mangel group, with the Mammoth Long Red variety the favorite. The Giant Feeding Half Sugar is a relatively new variety in Michigan which is gaining rapidly in popularity.

879a. Yields of root crops compared. Michigan.

	AVERAGE SIZE, POUNDS	AVERAGE PER CENT YIELD COMPARED TO CHECK	AVERAGE YIELD, TONS PER ACRE
Check (sugar beet)	1.063	1.	13.911
Giant feeding half sugar mangel	1.908	1.558	21.673
Danish giant sludstrup mangel	1.586	1.482	20.616
Kirsches Fodder mangel	1.921	1.471	20.463
Mammoth long red mangel	1.792	1.449	20.157
Amber globe turnip	1.082	1.340	18.640
Cowhorn turnip	1.022	1.278	17.778
Maud's carrot	.735	1.250	17.389
Oxheart carrot	.645	1.178	16.387
Mammoth or tankard rutabaga	1.480	1.110	15.441
Golden tankard mangel	1.357	1.084	15.080
Bangholm rutabaga	1.371	.934	12.993
Halflong drak red beet or halflong blood beet	1.037	.913	12.701
Am. purple top rutabaga	.936	.795	11.059
Average of Groups			
1—Mangel	1.705	1.409	19.601
2—Turnip	1.052	1.309	18.209
3—Carrot	.690	1.218	16.943
4—Rutabaga	1.262	.946	13.160
5—Garden beet	1.037	.913	12.701

880. Culture of Root Crops. Roots require a thorough preparation of the seedbed before sowing. They do best when planted in early spring and are usually planted as soon as danger of killing frosts is over. Most root crops can stand a light frost without injury.

Small acreages of roots may be planted with an ordinary garden drill, while for larger acreages a special beet drill is used or the ordinary grain drill may be substituted. The usual method of planting roots is to plant in rows, from 18 to 36 inches apart, 24- and 28-inch rows being common. The seed is covered about one inch in depth and the plants spaced 10 to 12 inches apart in the rows. Delwiche[7] recom-

[6] Cormany, C. E.—"Comparative Yields of Root Crops Tested." *Mich. Agr. Exp. Sta. Quart. Bul.* Vol. 10, No. 4, p. 170, May, 1928.

[7] Delwiche, E. J.—"Profitable Root Crops." *Wis. Agr. Expt. Sta. Bul. 300.* 1921.

mends that where the roots are planted in drills, that mangels be seeded at the rate of 3 to 4 pounds; carrots, 1 to 2 pounds; and turnips and rutabagas, 1 to 1½ pounds per acre. If the germination of the seed is unknown, he recommends increasing the amount 20 to 25 per cent per acre.

Clark and Minns[8] state that in New York the largest yield of mangels was obtained when 12 pounds of seed per acre was used, while with rutabagas seeding 2 pounds per acre gave the best results.

Most root crops, as in the case with sugar beets, require thinning, leaving one plant about every 10 to 12 inches in the row. The roots are harvested before freezing weather sets in and are stored so they will not be subject to freezing temperatures as otherwise the losses are excessive.

In the harvesting of the roots they are pulled, topped, and heaped in temporary piles and then placed in storage. Topping is done with a knife or the tops are wrung off by hand. Root crops are commonly stored in cellars, or if these are not available they are pitted by throwing into ricks and covering with alternate layers of straw and earth. Additional layers of straw and earth are added as the severity of the weather increases.

881. Feed Value of Roots. As a feed, root crops fill somewhat the same place in feeding rations as does silage. Various experiments have shown that the dry matter in roots is practically equal to the dry matter in corn silage. Considerable work with the feeding value of root crops has been done at the Copenhagen Laboratory for Agricultural Research.[9] One pound of solid in the root has been found to be equal to 1 pound of barley when fed to cattle. The addition of 100 pounds of mangels in the ration for dairy animals increased the milk yield 6.3 pounds per cow, while 125 pounds of turnips increased the milk yield 3 pounds per cow.

882. Rape as a Temporary Pasture Crop. Rape (*Brassica napus*) is much used in the United States as a temporary pasture crop for livestock. Rape, a very succulent plant, grows best during cool, moist weather and languishes when hot weather comes on. It will stand relatively severe frost. The crop is desirable as pasture for cattle, sheep, and hogs and in the South is used for fall feeding or very early spring feeding. In the North it is commonly seeded in the spring and is ready for grazing five or six weeks after seeding. The chief variety used in this country for forage is the Dwarf Essex. Seed is relatively inexpensive.

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[8] Clark, Charles F., and Minns, Edward R.—"Fertilizer and Seeding Experiments with Root Crops." *N. Y. [Cornell] Agr. Expt. Sta. Bul. 267.* 1909.

[9] *Fifty-fifth Annual Report*, p. 136. Laboratory for Agricultural Research. Copenhagen, 1904. Also, *Eighty-ninth Annual Report*, p. 16. 1915.

883. Methods and Rate of Seeding Rape. In the northern states[10] there are three common methods of seeding rape,—seeding alone on specially prepared land, seeding with small grain in the spring, and seeding between the rows of corn at the last cultivation. The rape seeded in the early spring usually produces the largest returns when seeded alone from the pasture standpoint. The rape is generally seeded alone for hog pasture or with oats when it is to provide pasture for sheep or cattle. For this method of seeding from 3 to 8 pounds of seed is used, being seeded in rows and cultivated or seeded solid with a drill or broadcast like small grain. When seeded with small grain, the small grain to be cut with a binder, the rape grows rapidly after the harvest of the grain crop, making an excellent pasture in the late summer and fall when other pastures, especially bluegrass and red clover, are inclined to be dry and of relatively little value. When seeded in this way the rape is often seeded broadcast two

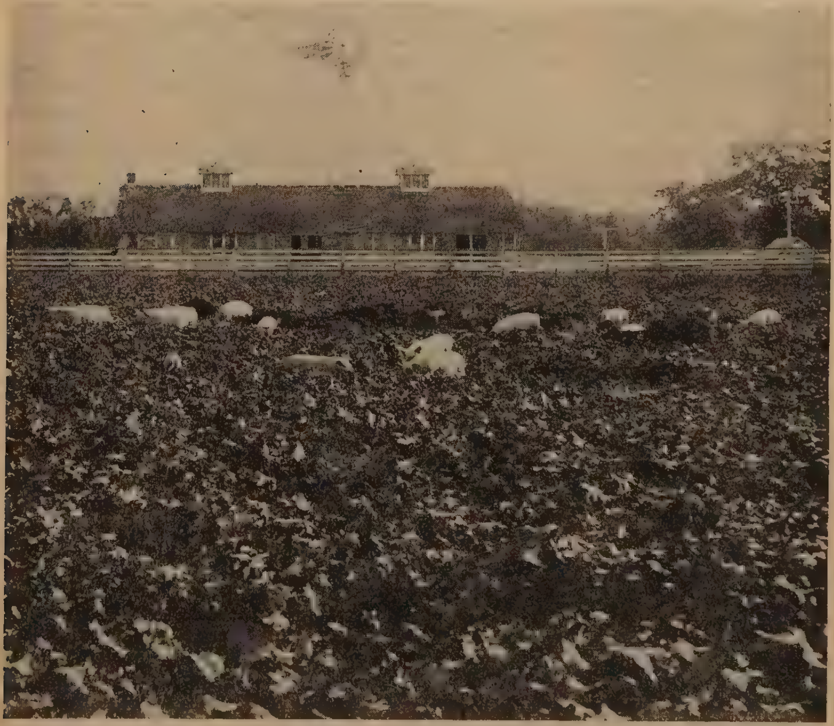

FIG. 151.—Hogs in rape pasture. *What is the carrying capacity of rape pasture; how soon after planting is it available and for how long a period? What precaution, if any, should be observed in seeding and in pasturing rape?*

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[10] Evvard, John M., and Hechler, W. R.—"Grow More Rape." *Iowa Agr. Expt. Sta. Circ. 53.* 1918.

or three weeks later than the small grain so as to give the grain crop the advantage in growth, as rape has sometimes interfered with the harvest of the oat crop, due to a rank growth of rape causing difficulty in the curing of the grain crop.

Seeding rape in corn at the time of the last cultivation is a rather common practice. Corn and rape can be harvested together by hogging down or by pasturing with sheep in the fall. Used in this way the seed is generally scattered at the rate of 3 to 5 pounds per acre with a hand seeder or by hand, immediately preceding the last cultivation. Seedings made at the Iowa station and at other corn belt stations indicate that this is not a certain method of getting a catch of rape, as failure results about half the time.

In the South, rape is generally seeded in September or October for fall and winter pasture and early in Febraury or March for early spring pasture. When seeded in the fall it commonly affords pasture from January until well into March, at which time fall-sown rape commonly seeds.

STUDY QUESTIONS ON CHAPTER XXXIV

1. Why do many of the European countries grow so large an acreage of root crops for stock feed?
2. Why do the farmers of the United States not grow more root crops for feed?
3. Give instructions for growing a crop of mangels.
4. Why is rape so widely used as an emergency pasture in the United States?
5. Give instructions for growing and pasturing a field of rape.
6. Give instructions for seeding rape in corn intended to be hogged off.

APPLICATION ASSIGNMENTS ON CHAPTER XXXIV

1. You are in need of a succulent winter feed for your dairy cattle. You can obtain a yield of 20 tons of mangels per acre or 8 tons of corn silage. Which will you grow? Explain.
2. You are considering rape for pasture. You will need to use this pasture for both cattle and hogs. Will you use the rape? If so, how? If not, what will you seed?

CHAPTER XXXV

POTATOES

The potato (*Solanum tuberosum*) belongs to the Nightshade family. It is related to the jimpson weed, horse nettle, buffalo burr, poison nightshade, tomato, egg plant, tobacco, and a large number of other plants, among which are 40 recognized tuber-bearing species, found generally in South and Central America and the southwestern part of the United States. Historically, the home of the potato has been credited to Peru.

884. Potato Production in Leading Countries. Production of potatoes in total bushels and the yields per acre for the seven leading countries of the world is as shown in Table *884a*.

884a. Potatoes: total production and average acre yield in leading countries; 1921-1925, inclusive.

	ACRES	YIELDS PER ACRE	PRODUCTION, BUSHELS
Germany	6,953,000	188	1,494,181,000
Poland	5,502,000	177	1,204,418,000
Russia	8,104,000	128	695,122,000
France	3,607,000	125	464,661,000
United States	3,697,000	107	453,396,000
Czecho Slovakia	1,580,000	151	333,236,000
United Kingdom	1,148,000	217	321,824,000

885. Description of the Plant. The potato, normally a perennial, is treated as an annual in our field culture. The above ground portion is an erect growing bush with hollow or pithy culms except at the nodes which are always solid. The stem is normally triangular between the nodes and rounded at the nodes. Below ground, the stem is usually round and solid. The leaves are compound, pinnate, with opposite pairs of large and small leaves alternating. The flowers are borne in clusters, usually appearing as though they were terminal, and producing, when fertilized, a seed boll, which is a round berry having two cells and many seeds.

886. The Tuber. Shortly after the stem appears above ground, stolons develop in the axiles of the scale leaves on the underground portion of the stem. These stolons lengthen for several internodes and ultimately swell at the tip to form tubers. The potato is thus not a root crop, but is a modified stem. The tuber is a shortened, thickened stem with scale leaves and at the axiles of the leaves lie the eyes of the potato. Each eye is a collection of buds lying generally in a depression.

887. Classification of Potato Varieties. There is no absolute key to the determination of potato varieties. New types with different combinations of characters are continually appearing on the market and old types appearing under new names. Stuart[1] classifies potatoes into 12 different groups on the basis of tuber shape, tuber, sprout, and flower color. Table *887a* on page 691 is from his classification.

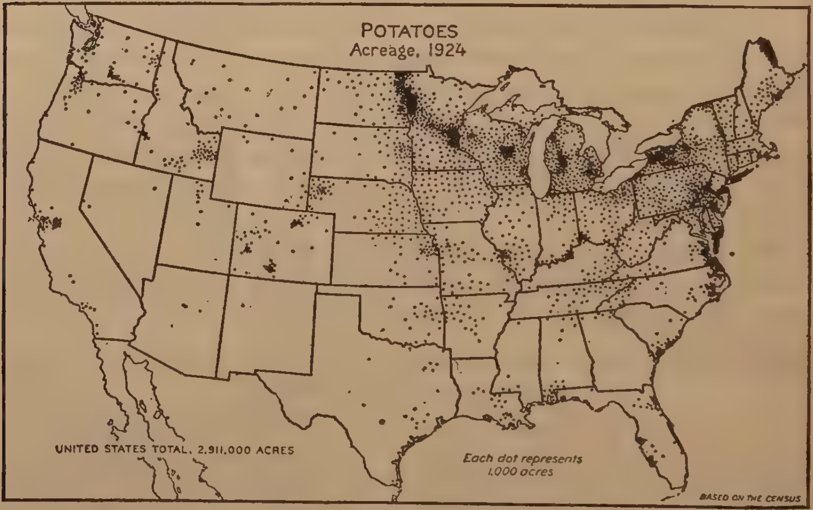
POTATOES
Acreage, 1924
UNITED STATES TOTAL, 2,911,000 ACRES
Each dot represents 1,000 acres
BASED ON THE CENSUS

FIG. 152.—Map showing the acreage of potatoes in the United States in 1924. *Account for the location of regions of heaviest potato production. Is the quality and yield of the crop, nearness to market, the climate, the character of the soil, or competition with other crops, the leading determinating factor?*

888. Adaptation of Potatoes. Potatoes are grown in practically all parts of the United States but commercial production is confined largely to rather definite areas, mostly located in the northern tier of states. The best potato soils are fairly loose, varying in texture from fine sand, to gravelly loam, to a silt loam. The soil should be fertile; in many sections substantial increases in yield have been obtained by the application of barnyard manure.

889. Size of Seed Pieces. The best size of seed piece to use and the best methods of cutting potatoes have been studied extensively.

Rosa[2] concluded from his studies in Missouri that the most

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[1] Stuart, William—"Group Classification and Varietal Descriptions of Some American Potatoes." *U. S. Dept. Agr. Dept. Bul. 176*, pp. 4-13. 1915.

[2] Rosa, J. T., Jr.—"Seed Studies with Irish Potatoes." *Mo. Agr. Expt. Sta. Bul. 191.* 1922.

887a. Classification of potato varieties. Stuart.

GROUP	TUBER SHAPE	TUBER COLOR	FLOWER COLOR	CHIEF VARIETIES OF THE GROUP
Cobbler	Roundish	Creamy white	Light rose, purple	Irish Cobbler
Triumph	Roundish	Creamy white, splashes of red, carmine, or solid red	Light rose, purple	Quick Lunch, Bliss's Triumph, White Triumph
Early Michigan	Oblong, elongate flattened	White or creamy white	White	Early Albino, Early Michigan, Early Puritan
Rose	Roundish, oblong, elongate flattened, or spindle flattened	White, pink or flesh colored	White and rose lilac	Early Rose, Early Vermont, Late Rose, Houlton Rose
Early Ohio	Round, oblong or ovoid	Flesh colored, numerous raised, russet dots	White	Early Ohio, Early Acme, White Ohio
Hebron	Elongated, somewhat flattened, sometimes spindle shaped	Creamy white, clouded with flesh color	White	Early Beauty of Hebron, Columbus Harbinger, New Queen
Burbank	Long, cylindrical to flattened slightly spindle shaped	White to creamy white	White	Burbank, White Beauty, California Russet, Russet Burbank
Green Mountain	Oblong, usually broad and flattened	Dull creamy or light russet	White	Green Mountain, Gold Coin, State of Maine, White Mt., Clyde, Idaho Rural, Rustproof
Rural	Broadly round-flattened to short oblong	Creamy white, some deep russet	Center violet, white points on cordla	Rural New Yorker, Arcadia, Late Petoskey, Great Divide
Pearl	Round, flattened to heart shape	Dull white, dull russet or brownish white, some bluish purple	White	Pearl, People's Blue Victor
Peachblow	Round to round-flattened or round-oblong	Creamy white splashed with crimson or solid pink	Purple	Early Peachblow, Jersey, Peachblow, McCormick, Dykeman
Up-to-Date	Oval	White	Light red to purple	Up-to-date, Factor, Dalhousie, Field Marshal (russet skin)

profitable size of seed piece to use is just a little over an ounce. His work was with the Early Ohio potato and covered a period of four years.

Stuart[3] *et al.* found small uncut tubers between 1 and 2 ounces at least as good as sets cut from larger potatoes.

They also found that seasonal conditions have a very definite influence upon the yield secured from different sized sets. An abundance of moisture and plant food throughout the growing season favors whole and large sized cuts, whereas a lack of these two favors medium sized cuts because fewer tubers are produced and they have a better chance to reach marketable size. Whole potatoes varying from 2 to 6 ounces produced from 3 to 7 stems for the 2- to 6-ounce sets respectively. With halved seed, 2 stems were produced by 2-ounce sets and 4 by 6-ounce sets. With quartered sets, 2 stems were produced regardless of the weight of the set.

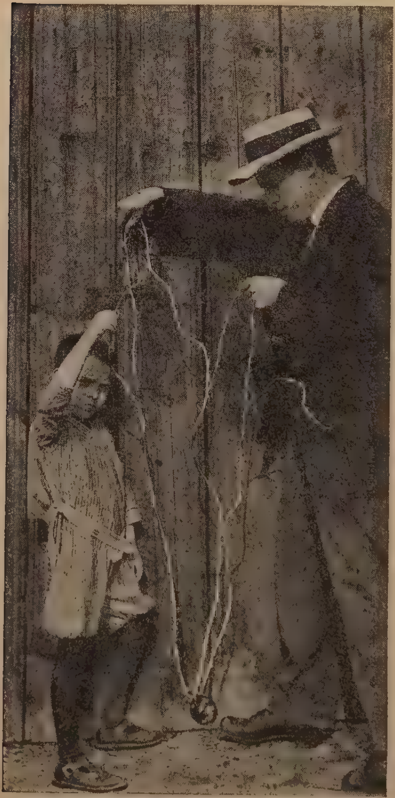

FIG. 153.—Sprouts from a single potato tuber stored in a wet cellar.

A large number of investigators have compared the results secured from the use of different sized seed sets. About half report that the yield increases with the weight of set or seed; the other half found that the net crop from the small sets was as great as from the large ones. Stuart[4] *et al.* suggest that the reason for the lack of agreement lies in the failure to give careful study to varying the spacing given each set according to its size.

Zavitz[5] reports a six-year comparison with whole, medium, and small uncut potatoes for seed planted at various rates. Table *889a.*

890. Number of Eyes on a Set. Zavitz planted sets with 1, 2, 3, 4, and 5 eyes per set. The yield of potatoes as a five-year average was 139.8, 151.3, 153.9, 161.3, and 165.1, bushels per acre. Zavitz also tested

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[3] Stuart, William, *et al.*—"Size of Potato Sets: Comparisons of Whole and Cut Seed." *U. S. Dept. Agr. Dept. Bul. 1248.* 1924.

[4] *Ibid.*, pp. 35-37.

[5] Zavitz, C. A.—"Potatoes." *Ontario Dept. Agr. Bul. 239*, pp. 42-47. 1916.

889a. Size of potato seed sets and yield Zavitz.

Preparations	Percentage of Crop Marketable (Average Six Years)	Yield per Acre (Average Six Years) Bushels	Yield per Acre Less Seed Used (Average Six Years) Bushels
Large whole, 1 foot apart	79.25	338.03	110.98
Large whole, 2 feet apart	84.00	247.75	133.00
Large whole, 3 feet apart	85.83	200.26	125.49
Medium whole, 1 foot apart	82.07	274.01	179.81
Medium whole, 2 feet apart	87.37	210.36	163.39
Small whole, marketable, 1 foot apart	87.83	201.03	176.54
Medium cut in 2, 1 foot apart	83.95	211.32	163.45
Medium, 2 eyes in a piece, without seed ends, 1 foot apart	90.57	153.21	135.45
Medium, 1 eye in a piece, without seed ends, 1 foot apart	91.39	106.46	96.38
Medium, seed ends, 1 foot apart	85.57	104.24	98.22

single eye sets from the middle portion, stem end, and seed end of the potato. The yields as a five-year average were 174.8, 167.7, and 162.0 bushels per acre, respectively.

Hardenburg[6] reviewed the literature on the number of eyes per set and concluded that as the eyes on each set increase in number the total yield of potatoes increases, but the yield of marketable potatoes decreases.

891. Source of Seed. Rosa[7] compared the average yield of three varieties of northern grown, fall home-grown seed, and spring home-grown seed for Missouri conditions. In every case the spring home-grown class produced the poorest results, having a high per cent of culls and low yields in bushels per acre. Fall home-grown seed gave best results one year and the other two years closely approached the northern seed in No. 1 potatoes. He suggests that in many cases farmers can profitably grow a fall crop of potatoes to be used for seed the following spring, if care is used that the right variety and strain is selected.

Emerson[8] for four years compared northern grown seed with seed grown under mulch in Nebraska and states that for each 100 pounds produced on the average by mulched seed tubers the northern grown seed yielded an average of 98 pounds. Seed grown without mulching was much inferior to the mulched plot and to the northern grown seed.

[6] Hardenburg, Earle V.—"A Study, by the Crop Survey Method, of Factors Influencing the Yield of Potatoes." *N. Y. [Cornell] Agr. Expt. Sta. Mem. 57,* p. 1220. 1922.

[7] Rosa, J. T., Jr.—"Seed Potatoes for Better Yields." *Mo. Agr. Expt. Sta. Circ. 106.* 1922.

[8] Emerson, R. A.—"Home Mulched *vs.* Northern Seed Potatoes for Eastern Nebraska." *Nebr. Agr. Expt. Sta. Bul. 146.* 1914.

892. Time of Planting. Potatoes use the cool part of the growing season. In the cotton belt planting is done in January or February, for the early crop potatoes. In the northern part of the United States, plantings are not made until after May 1. Planting of the late crop of potatoes is done at a later date. The date of planting is usually governed by the character of the growing season. A long, hot, dry spell during the period when the plant is developing its tubers will result in a low yield, while if it is wet and cool during this period, a good yield is assured, if good cultural methods are used.

893. Rate of Planting. The rate of planting and the amount of the seed needed per acre depends upon the size of the seed piece used, the number of plants in the row and the width of the row. In general, in the United States, not more than 15 bushels of seed potatoes are required per acre. According to Stuart[9] the quantity of seed required in different parts of the United States varies from 5 to 18 bushels per acre, with an average of 8.6 bushels.

Stuart found that seed required per acre with one-half ounce pieces in rows 48 inches apart and 36 inches apart in the row was 1.9 bushels, while with rows 30 inches apart and 8-inch spacing and two-ounce pieces 54.4 bushels per acre was required. In general, the 14-inch spacing in rows 30 inches apart with one-ounce seed pieces required 15.6 bushels per acre. No one rule can be given for distance of spacing. The nearer the soil and weather conditions approach the ideal the larger the seed pieces and the closer the planting will be for maximum yields. In general, early maturing varieties are planted more closely than late maturing sorts.

894. Depth of Planting. Zavitz[10] reports an experiment in which potatoes were planted 1 inch, 3 inches, 5 inches, and 7 inches deep. He found that the depth of the new crop below the surface, as an average of three years, was 1.7, 3.0, 4.0, and 4.9 inches, respectively. The marketable crop, as a five-year average, was 177, 188, 188, and 164 bushels per acre, respectively.

The general depth of 4 inches seems about right in the United States, varying with the method of culture to be followed, being somewhat shallower if the ridged method of cultivation is to be followed and depending upon the soil type. In heavy, cold soil the planting is shallower than in light, sandy soil. With early planting the depth is usually less than with later planting.

895. Cultivation of Potatoes. Potatoes are either cultivated level or by what is called the ridge system. In sections where hot, dry weather is likely to prevail during the time the tubers are forming, level culture is generally practiced, while if cool, moist weather is to be expected, the ridge system is used. In general, the ridge system is used in Maine, New York, and the irrigated sections of the West. In the Central North and in the South generally the level system is used. In the early part of the cultivation period the harrow and the weeder are commonly used; while in the later part relatively shallow cultivation, as for corn or other crops, is the rule.

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[9] Stuart, William—"Production of Late or Main Crop Potatoes." *U. S. Dept. Agr. Farmers' Bul. 1064.* 1919.

[10] Zavitz, C. A.—"Potatoes." *Ontario Dept. Agr. Bul. 239*, p. 51. 1916.

Stuart[11] states that when the soil is well filled with roots, in the absence of rain soon after cultivation, a single cultivation may reduce the yield fully one-half, and as a rule cultivation should cease soon after the tubers have set.

896. Time and Method of Harvesting. Potatoes are ordinarily harvested with an elevator type of digger except where small acreages are grown. With small acreages, a simple plow-like digger serves very well.

The date of digging has been tested at several stations. Kohler[12] harvested potatoes in Minnesota at one-week intervals on July 31, August 7, August 14, August 23, and August 30. On July 31, none of the vines were dead; on August 30, 99 per cent of the vines were dead. The yields in marketable potatoes were 10.9, 62.3, 115.4, 182.1, and 226.8 bushels per acre, respectively.

In general, potatoes are harvested when they are mature. Sometimes an early market induces earlier harvest, but commonly they are left in the ground until time to put in storage, and harvested only early enough to avoid all danger of chilling.

897. Storage of Potatoes. After digging, potatoes are commonly left for a few hours in the sun to dry. The storage house or place of storage should be dark, with a temperature range of between 35° and 40° F., and with sufficient ventilation provided to remove foul air and excess moisture. Potatoes should be clean and free from dirt when placed in storage. Diseased and badly cut or bruised tubers should be sorted out before the crop is placed in storage.

898. Potato Breeding and New Varieties. The potato is commonly self-fertilized. Practically all varieties of potatoes produce flowers when grown under favorable conditions. After a favorable strain is produced from seed, it is ordinarily kept pure as a result of the vegetative method of reproduction. In general, breeding by crossing or self-fertilizing of the seed and the use of seedlings is the principal way in which new varieties are produced. Strains of the potato can produce bud sprouts, but as a means of producing superior new types, they do not occur commonly enough to give promise of usefulness.

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[11] Stuart, William—"Production of Late or Main Crop Potatoes." *U. S. Dept. Agr. Farmers' Bul. 1064.* 1919.

[12] Kohler, A. R.—"Potato Experiments and Studies at University Farm in 1909." *Minn. Agr. Expt. Sta. Bul. 118,* p. 109. 1910.

Hill selection is commonly used and usually gives good increase in yield.

Stewart[13] reports a test in which high yielding and low yielding hills were selected from three potato varieties. As a six-year average the acre yield was 60.9 per cent greater for the high yielding strains than for the unselected seed and the average size of tuber 24.4 per cent greater.

STUDY QUESTIONS ON CHAPTER XXXV

1. Give the botanical relationships of the potato.
2. Prepare a chart which will show the relative importance of the potato in the various countries.
3. Indicate on a world map the climate adaptation of the potato.
4. Give instructions for seed preparation, planting, cultivation, and harvesting of the potato crop.
5. What is the method used in improving a strain or variety of potatoes? How are new varieties of potatoes secured?
6. How do potatoes compare in value per acre with other standard field crops? How do they compare in net value per acre?
7. What factors will determine the advisability of seeding a considerable acreage of potatoes in any particular locality?

APPLICATION ASSIGNMENTS ON CHAPTER XXXV

1. Potato prices were very low last season. You have grown 20 acres each year for the market and are equipped for handling them. Will you grow potatoes this year? Explain.
2. You have been using certified, northern-grown seed potatoes but are thinking of saving your own seed this year. How will you do this? Ordinarily, is it better to buy from the North or save your own seed potatoes? Explain.
3. Your seed potatoes are about 2 inches in diameter and but slightly longer than thick. How will you prepare them for planting? Why?
4. Prepare an outline giving the assentials for the most successful production of a crop of potatoes for the early market. For a crop of late potatoes.

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[13] Stewart, George—"Potato Improvement by Hill Selection." *Utah Agr. Expt. Sta. Bul. 176.* 1920.

CHAPTER XXXVI

STORAGE AND MARKETING

The function of the farmer in producing a high quality of crop represents but one field of his activities. It has been assumed that farmers have completed their task when they grow the crop. However, in recent years, many groups of farmers not only have been producing the crop but also processing and marketing it in so far as possible. This entrance of farmers into marketing activities has resulted in bringing home to the farm folk a better understanding of the laws governing prices. Periods of low prices, formerly readily attributed to a manipulated market, are now generally being considered from the standpoint of supply and demand, and farmers are watching the general economic conditions of the country more closely than they formerly did.

899. Markets. A market is a place where buyers and sellers meet to transact business. There are many types for the different commodities. Usually interest centers in two: local markets, at which farmers sell their product direct to the users or to the dealer, and the central markets, at which are found the Boards of Trade or the various produce exchanges, where commission merchants, brokers, the agents of coöperatives, speculators, and others operate.

The price of a commodity is determined by the offers made to buy being met by offers to sell, resulting in the exchange of ownership. The average of the figures at which these transactions take place is called the price for that day at that market. These transactions are influenced by the amount of the commodity available and the prospects for a future supply, as well as by other general economic conditions. A trader wishing a lower market is termed a "bear," while one who desires a higher one is termed a "bull." "Bears" and "bulls" stress market information, tending to cause a reaction in price favorable to them.

900. Market Practices. Locally the market usually consists of one or a few buyers bidding on the commodity, the highest bidder getting the product or the grower holding for better prices or shipping direct to a larger market. In most commodities, local men buy on an average price influenced by the market conditions and the general run in grade coming in at that season of the year. In certain commodities an attempt is made to grade the product coming into the local market but it is not accurately done. At the central markets grading of the commodity is often done by federal inspectors and the value of the shipment more accurately determined.

In dealing on the central market, rules are observed strictly and protection is given the dealers from unscrupulous or fraudulent transactions. Practices most generally misunderstood are hedging and dealing in futures.

Hedging is a method used to protect the owner of a commodity from loss due to fluctuations in price which may occur before the commodity can be put on the market. A typical hedge will serve to illustrate this practice. An elevator purchases 5000 bushels of wheat today, paying a price justified by the market. Immediately the manager sells 5000 bushels of wheat by wire at a price which gives him his margin of profit plus the cost of getting his wheat to market. When his wheat arrives, regardless of whether the market has gone up or down, he receives only his margin of profit. If the market has gone up he loses on the wheat he had previously sold and makes a like amount on that which he purchased and delivered. In case of a drop, the reverse is true. Hedging is considered necessary "insurance" by many of the legitimate dealers in a commodity.

901. Future Trading. The purchase of the hedge offered in hedging grain depends on the activity of a group of men known as "speculators" who either buy or sell a commodity, depending on whether they think the market will rise or fall by a specified time in the future. A commodity may be sold several times on the future market and the hedge previously made against it taken up. Speculation through buying and selling futures is claimed to prevent wide fluctuations in the price of the commodity.

902. Costs of Storage. In determining the cost of storing a given crop on the farm where it was produced there are a number of items which should be taken into consideration; as for example, interest and depreciation on the storage building, insurance, a reasonable interest on the value of the crop and losses in value from rats, mice, insects, etc. Regular elevators in terminal markets are permitted to make a storage charge of 1¼ cents per bushel for the first 10 days or part thereof on grain, flax, seed, etc., in good condition and $\frac{1}{20}$ cent for each month thereafter. The usual charge for corn is 1 cent per bushel for unloading (including 5 days free storage), then $\frac{1}{30}$ cent for each month thereafter.

Charges for storage vary with the nature of the product. Warehouse rates and insurance rates for cotton are comparatively high, due to the fire hazard. To the other costs of storage must be added the interest charge on the money value tied up in the crop.

The loss in weight from shrinkage or loss of moisture must also have consideration.

903. Shrinkage in Ear Corn during Storage. The moisture content of corn which is to be stored is one of the most important factors to be considered in the handling of the crop. First, there is the danger of loss from the stored product heating and molding; and second, the shrink due to the loss of moisture in curing. Often the grower can afford to cure the crop in cribs before marketing, as the buyer must otherwise offer a price sufficiently low to allow for the water content, the lower grade, and the cost of shipment, as well as compensating himself for the risk which he is assuming in handling a crop which may heat and spoil on his hands.

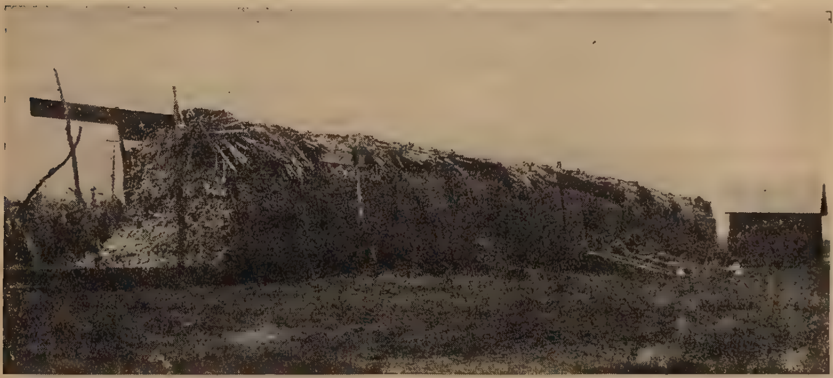

FIG. 154.—Makeshift storage of ear corn. *Compare the cost of storage in a rat-proof, weather-proof crib with the loss from rat damage and weathering, which may result here.*

Burlison and Allyn report a test [1] at the Illinois station in which each year about 300 bushels of corn were hauled directly from the field and placed in an open crib, protected by a tight roof and slat sides and left until the next crop was gathered. Four times each month the crib and its contents were weighed to determine the shrinkage. The average of the four weighings was taken as the monthly average from which to compute the shrinkage of the corn. The 9-year average shrinkage by months, together with the monthly averages, is given in Table *903a*. An 8-year average for a small crib at the Iowa Station,[2] handled in a similar manner, is shown in the same table.

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[1] Burlison, W. L., and Allyn, O. M.—"Prices and Shrinkage of Farm Grains." *Ill. Agr. Expt. Sta. Bul. 183*, 1915.

[2] Wilkins, F. S.—"Moisture in Corn." *Unpub. Thesis 1915.* Iowa State College Library.

903a. Per cent shrinkage of crib corn by months. Illinois and Iowa.

MONTH	ILLINOIS		IOWA	
	9-Year Average	Shrink per Month	8-Year Average	Shrink per Month
Nov.	1.33	. . .	5.2	5.2
Dec.	3.26	1.93	6.9	1.7
Jan.	4.16	.90	7.5	.6
Feb.	5.48	1.32	7.8	.3
Mar.	6.95	1.47	9.7	1.9
Apr.	9.99	3.04	12.8	3.1
May	13.10	3.11	14.7	1.9
June	15.29	2.19	16.3	1.0
July	16.15	.86	17.3	1.0
Aug.	16.61	.46	17.8	.5
Sept.	16.39	(—.22)	18.2	.4
Oct.	16.54	.15	18.2	.0
Nov.	16.30	(—.24)		. .

Welton (Ohio)[3] reports, as an 8-year average, the per cent shrink per month in 100 pounds of well-matured ear corn, placed in a wooden box covered with wire netting and protected from the weather. The per cent shrinkage is given for each month, calculated from November 1, so that each month's shrink includes the total loss to date.

Ohio also reports the 5-year average shrink of corn which had an average of 30.3 per cent of moisture in the grain and 45.2 per cent in the cob when cribbed.

903b. Per cent shrinkage of ear corn by months. Ohio.

	SHRINKAGE IN MATURE CORN; 8-YEAR AVERAGE	SHRINKAGE IN SOFT CRIB CORN; 5-YEAR AVERAGE
Dec. 1	5.28	4.75
Jan. 1	7.03	7.90
Feb. 1	8.11	10.30
Mar. 1	9.42	12.45
Apr. 1	11.62	18.20
May 1	16.00	23.55
June 1	19.03	27.45
July 1	20.03	28.85
Aug. 1	20.41	29.20
Sept. 1	20.37	28.65
Oct. 1	19.18	28.15

904. Shrinkage of the Small Grains. Small grains, when harvested by ordinary methods, do not have a high moisture content and the shrink is slight. Harris and Thomas[4] found that in arid regions in

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[3] Williams, C. G., and Welton, F. A.—"Corn Experiments." *Ohio Agr. Expt. Sta. Bul. 282*, p. 106. 1915.

[4] Harris, F. S., and Thomas, G.—"The Change in Weight of Grain in Arid Regions during Storage." *Utah Agr. Expt. Sta. Bul. 130*, p. 313. 1914.

Utah there was a gain of from 2.5 to 4.5 per cent in weight of grain during the fall after harvest. In every case, there was a gain in weight during the winter and a loss during the summer, but the grain weighed less at threshing than at any time later.

Smith [5] quotes work at the California station in which oats gained 19.8 per cent in weight when exposed to a saturated atmosphere at 64.4° F. for 18 days and lost 9.3 per cent from normal when exposed for the same period to air artificially dried. Wheat gained 18.8 per cent and lost 6.2 per cent under similar conditions. Barley gained 20.4 per cent and lost 7.8 per cent.

Work at the Michigan station, also reported by Smith, indicates that wheat fluctuates in weight according to the dryness of the air. Oats lost 3 per cent in one case, approximately 2 per cent in two trials, and only 7 pounds per 100 bushels in a fourth trial.

905. Holding Corn for Market. Shrinkage is important in determining the desirability of holding grain or of selling it at harvest time. With reference to the storage of corn, the Iowa Station found [6] that the cost of carrying corn on the farm is one cent a bushel a month. Corn storage in the crib until June or August in a bumper crop year practically always resulted in a substantial gain, while in a short crop year it resulted in a loss. In normal years the shrink and storage costs are usually roughly offset by the seasonal rise in price. In such seasons any profit resulting comes from an improvement in the grade of the corn. It is pointed out that if grades are high in December not much profit may be expected from holding the crop until June or August.

906. Shrinkage in Hay. Information on the shrinkage of hay in storage will be found in the chapter on Hay. **(679) (680)**

Grain, Hay, and Cotton Grading

907. Grain Grading. When grain reaches the central markets, cash settlement for the grain is based on Federal Standard grades. At each market, licensed grain inspectors are maintained by the Government. When a car of grain comes into the yards, the buyer or seller may call for an inspection. One of the crew of inspectors goes to the car, opens it and, using a probe or trier, takes a representative sample of the grain.

The probe used is a cylinder, 5 feet long, with slotted openings down the full length; the bottom is closed and inside the one cylinder is another cylinder with similar slotted openings. The probe is thrust

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[5] Smith, C. D.—"Shrinkage of Farm Products." *Mich. Agr. Expt. Sta. Bul. 191.* 1901.

[6] Shepherd, G. S.—"When Shall We Sell Our Corn?" *Iowa Agr. Expt. Sta. Circ. 113.* 1929.

905a. The average price for the United States, by months, which producers received for certain commodities and the per cent of the total marketed each month.

	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	AVER.
Farm Prices for 1921 to 1925, Inclusive													
Wheat	1.23	1.26	1.25	1.21	1.23	1.20	1.08	1.09	1.08	1.10	1.13	1.17	1.13
Rye	.83	.85	.83	.78	.78	.76	.78	.77	.74	.77	.76	.80	.78
Corn	.74	.76	.77	.77	.79	.81	.84	.88	.86	.82	.71	.71	.78
Oats	.42	.43	.43	.42	.42	.43	.41	.38	.37	.38	.38	.40	40
Barley	.59	.60	.61	.61	.61	.61	.60	.58	.56	.57	.57	.58	.58
Flax	2.21	2.31	2.34	2.34	2.37	2.28	2.20	2.13	1.98	2.01	2.03	2.10	2.07
Cotton	.22	.22	.22	.22	.22	.22	.22	.21	.21	.22	.22	.22	.22
Per Cent of Crops Marketed Each Month, 1925													
Wheat	4.7	4.0	3.1	3.0	3.0	4.1	14.7	18.8	18.4	10.6	8.6	7.0	
Rye	6.6	4.6	3.1	2.4	2.8	2.8	5.2	19.2	23.3	12.4	8.7	8.9	
Corn	12.1	10.4	8.5	5.3	7.1	8.2	5.1	7.6	5.9	5.9	9.3	14.6	
Oats	6.1	6.2	5.1	4.2	4.5	5.6	10.4	22.4	13.1	9.3	6.3	6.8	
Barley	4.0	3.4	3.1	2.0	3.3	6.9	16.4	19.1	18.4	11.7	6.6	5.1	
Flax	2.7	2.0	1.8	1.5	1.9	2.1	1.1	11.1	34.3	23.5	12.4	5.6	
Cotton	6.5	4.2	3.1	2.3	1.7	2.1	1.6	6.5	19.3	23.1	17.6	12.9	

down into the grain with the openings closed by turning the inside cylinder half around. When the inside cylinder is again turned half round the grain flows in. In this way a representative sample of the grain from the top to the bottom is obtained. Four or five probes are taken from each car. One and one-eighth pints of the sample are put in an air-tight container and the remainder into a waterproofed sample bag.

The two lots of grain are taken to the grain inspection laboratory for the determination of class and grade. The grain in the air-tight container is used for the determination of moisture percentage. The sacked sample is examined; first, for objectionable odors such as that of wild onions or garlic, for bleaching, scouring or clipping, for smut and ergot, and for the presence of live weevils or other insects (called bran bugs by the inspectors) injurious to stored grain. If any such objectionable character is found a brief statement to that effect is added to the grade designation; i.e., "No. 2 Hard winter, smutty," or "No. 3 White corn, weevilly."

In case of wheat the first exact determination is for dockage. Dockage includes sand, dirt, weed seed, weed stems, chaff, straw, grain other than wheat, and any other foreign material which can be removed readily from the wheat by the use of sieves or other practicable devices. The percentage of dockage by weight is added to the grade designation. Determinations for all other factors in wheat are calculated on a dockage free basis. After the weight per bushel is obtained, small lots are used for determinations of total damage, heat damage, foreign material, kind of wheat, hardness, and amount of mixture with wheat of other classes.

In corn, determinations for heat damage, total damage, and color are made after the cracked corn and foreign material have been removed. The weight per bushel and per cent of foreign material and cracked corn are obtained from the original sample.

In oats, moisture, weight per bushel, condition and general appearance, sound cultivated oats, heat-damaged grain, foreign material, wild oats, and other colors of cultivated and wild oats are the determinations made.

In rye, determinations are made for dockage, moisture, weight per bushel, total damage, heat-damage, foreign material other than dockage, ergot, smut, and objectionable odors.

908. Federal Grain Standards.[7] In the Federal Standards, a class is the largest group. Each class is divided into sub-classes and each sub-class into grades.

In grading grain, each requirement must be filled. A sample making a particular grade is everything except one factor must be in the grade as determined by that one factor. Details on the requirements of the different grades and classes can be had from the Bureau of Markets, United States Department of Agriculture.

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[7] *Handbook of Official Grain Standards.* U. S. Dept. Agr. 1928.

909. Grade of Grains Delivered at Terminal Markets. The number of cars of oats, corn, and wheat delivered at the terminal markets in the United States during the period of one year and the class and grade of this grain will be of interest.

909a. Number of cars of grain delivered at terminal markets in the United States during the period Sept. 1, 1922, to Sept. 1, 1923, and the kind, class, and grade of this grain.

CLASS	No. 1	No. 2	No. 3	No. 4	SAMPLE	TOTAL
Number of Cars of Oats of Each Grade						
White[a]	2,101	45,333	94,390	16,559	4,011	162,384
Red	329	1,531	1,272	340	124	3,596
Gray	46	31	27	25	7	136
Mixed	72	452	295	80	498	1,397

CLASS	No. 1	No. 2	No. 3	No. 4	No. 5	No. 6	SAMPLE	TOTAL
Number of Cars of Corn of Each Grade								
White	3,747	36,699	16,292	3,212	610	476	532	58,568
Yellow	13,406	74,393	62,441	15,019	2,774	2,020	1,581	171,634
Mixed	4,427	33,471	20,199	6,030	886	1,030	1,598	67,641

CLASS	No. 1	No. 2	No. 3	No. 4	No. 5	SAMPLE	TOTAL
Number of Cars of Wheat of Each Grade							
Hard Red Spring I	85,187	21,703	11,584	5,380	2,276	1,324	127,454
Durum II	9,776	28,983	9,213	4,646	1,290	1,016	54,924
Hard Red Winter III	21,302	94,155	66,412	20,271	6,282	19,087	227,509
Soft Red Winter IV	2,779	22,965	22,224	9,621	2,962	12,231	72,782
White Wheat V	5,695	10,860	6,416	1,786	406	353	25,516
Mixed	13,281	31,861	15,509	6,762	2,410	4,987	74,810

[a] White class—includes yellow.

A total of 7,589,299 bushels of dockage was assessed on wheat in the year from September 1, 1922, to September 1, 1923.

910. U. S. Standards for Hay.[8] Groups as established by the United States Department of Agriculture are as follows: 1. Timothy and clover; 2. Alfalfa and alfalfa mixed; 3. Prairie; 4. Johnson and Johnson mixed; 5. Grass hay; 6. Mixed hay. The division of each group into classes is based on the kinds and mixtures of hay that are of commercial importance.

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[8] *Handbook of Official Hay Standards.* U. S. Dept. Agr. 1928.

Information on the requirements for the different groups, classes and grades of hay can be had from the *Handbook of Official Hay Standards,* United States Department of Agriculture, 1928.

FIG. 155.—Determine the grade of a car of baled hay at the terminal market. *What are the factors which determine the grade of hay and what is the relation between grade and selling price?*

911. Cotton Grading. The recently adopted Universal Cotton Standards recognize 9 grades of white cotton, 3 each of blue-stained, gray, light-stained, and yellow-stained, 5 of spotted, and 6 yellow tinged. In the accompanying chart Palmer has shown the 7 recognized colors and the grade range in each.

911a. Grades and colors of the universal standards for American upland cotton.

Blue-stained	Gray	Standards for Grades of Upland Cottons, White	Spotted	Yellow-tinged	Light-stained	Yellow-stained
		1 or M.F.				
		2 or S.G.M.		2 T.		
3 B.	3 G.	3 or G.M.	3 Sp.	3 T.	3 L.S.	3 S.
4 B.	4 G.	4 or S.M.	4 Sp.	4 T.	4 L.S.	4 S.
5 B.	5 G.	5 or M.	5 Sp.	5 T.	5 L.S.	5 S.
		6 or S.L.M.	6 Sp.	6 T.		
		7 or L.M.	7 Sp.	7 T.		
		8 or S.G.O.				
		9 or G.O.				

Gray, spotted, and light-stained are grades intermediate between the two on either side of these in the chart. Grades above the black lines are deliverable on future contracts as provided in Section 5 of United States Cotton Futures Act.

The grades of white cotton in order are (1) Middling Fair, (2) Strict Good Middling, (3) Good Middling, (4) Strict Middling, (5) Middling, (6) Strict Low Middling, (7) Low Middling, (8) Strict Good Ordinary, (9) Good Ordinary. The grade is determined by color, foreign material such as leaf particles, trash, hulls, motes (immature seed). dirt, etc., and condition of ginning, whether smooth or containing neps (tangled masses of fibers), and gin-cut staple (chewed-up stringy appearance of cotton). The placing of a sample of cotton in the correct grade is done accurately by direct comparison with standards. Considerable experience is needed before classing can be done without the standards and occasional comparisons are desirable even then.

Middling is basis cotton on which prices are figured. Cotton grading below Good Ordinary is usually sold on sample and is called "dogs."

Cotton value depends to a very large extent on the length of staple (length of fibers). The official standards recognize differences in staple length below ¾ inch and from ¾ inch up to 1½ or 1¾ inches, depending on the type of cotton, by 32nds of an inch. Premiums paid for extra staple length are not definite or fixed, but vary with the demand for that particular length of staple. In 1920 high staple premiums were paid 1¼-inch staple brought a premium of 46 cents per pound, while in 1923 staple premiums were low, the 1¼-inch staple bringing only 2.5 cents premium per pound.

Similar variations are found in the differences paid for the better grades of cotton, although the differences are not so wide.

Palmer[9] has given detailed instructions in determining (pulling) the staple of cotton.

STUDY QUESTIONS ON CHAPTER XXXVI

1. What is a market? What are the factors which ordinarily determine the price at which our crops sell on the general market?
2. What is "future trading" and why do producers object to it?
3. You are offered 75 cents per bushel for your corn on November 15 when it contains 30 per cent of moisture. Including interest and a fourth of a cent per bushel storage charge, what price will you need to secure the following April to break even?
4. You have 1,000 bushels of hard red winter wheat which grades No. 2. On August 15 you are offered $1.20 per bushel direct from the thresher. Allowing interest and storage charges what price will be the equivalent on April 15 following?
5. Explain the reasons for the establishment of federal grain standards for grades of grain and hay.

APPLICATION ASSIGNMENTS ON CHAPTER XXXVI

1. If you were given the responsibility of securing a fair price for wheat to the grower, in what way would you change the present system of marketing?
2. In what ways does the present system adjust over and under production? What better way would you suggest?
3. You have a car of wheat for sale. What steps will you take in selling it in order to be certain of receiving all it is worth?
4. You sold a car of alfalfa. By the time it had reached the buyer it had shrunk 5 per cent in weight. Who should stand this loss? Explain.
5. You grow a large acreage of corn each year for the market. Under what crop and seasonal conditions will you find it most to your advantage to hold your crop until the following season before selling?

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[9] Palmer, A. W.—"The Commercial Classification of American Cotton." *U. S. Dept. Agr. Dept. Circ.* 278. 1924.

CHAPTER XXXVII

WEEDS

A weed has been defined as a plant out of place. Certain species of plants are commonly called weeds regardless of where they are found growing. Some plants are weeds under certain conditions, while under other conditions they may have considerable value.

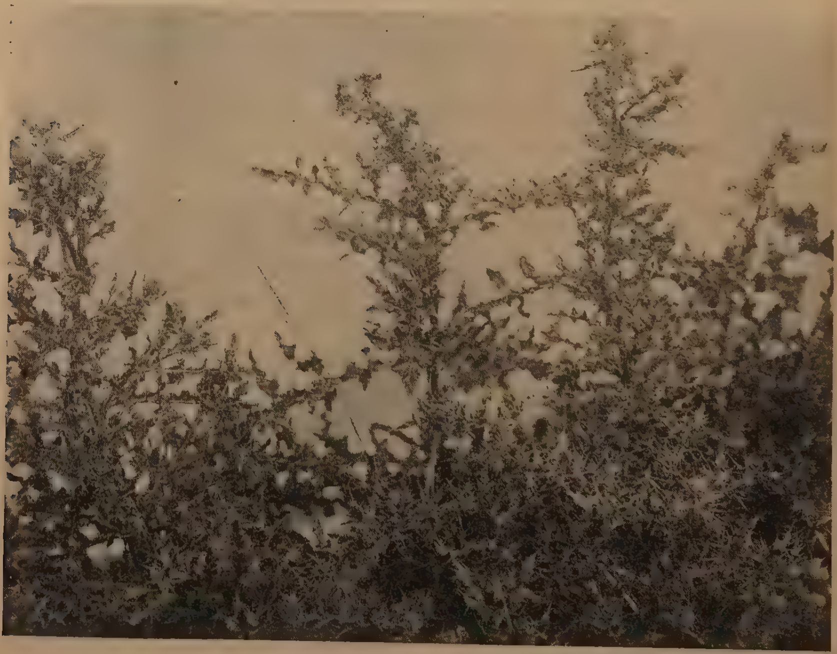

FIG. 156.—Vigorous specimens of the Canada thistle, one of the most troublesome of the noxious weeds. *Is it practically possible to entirely eradicate a growth of Canada thistle? What is the most practical and efficient procedure?*

912. Classification of Weeds. The growth habit of weeds has been used to classify them into annuals, biennials, and perennials. An annual completes its life cycle in one year. Annuals have been divided into summer annuals,—those in which the seed germinate in the spring and the plants grow during the summer and die in the fall, and winter annuals,—those in which the seed germinate in the fall and make a limited growth, maintain themselves through the winter and mature seed early the following season. Biennials are plants requiring two years, and may reproduce (1) by seed only; (2) by creeping root stalks as well as by seed, and (3) by bulbs, bulblets, or seed. The method of controlling a particular weed is usually associated with the length of its life period, whether one, two, or three years.

913. Fifty of the Worst Weeds. In Table *913a*, pp. 710-714, is presented an alphabetical list of over 50 of the worst weeds in the United States, with information which will aid in their identification. Their duration and the portion of the country in which each has been most troublesome is also indicated.[1]

914. Noxious Weeds. Weeds which are particularly troublesome to control or to exterminate are usually referred to as "noxious." In many instances weeds which are noxious in one state with the particular climatic conditions and cropping practices found there are not troublesome in some other states. There are other weeds which may be particularly dangerous but which are not included in the noxious list in the seed laws because seed of these weeds are of such a character that they are never found in commercial seed.

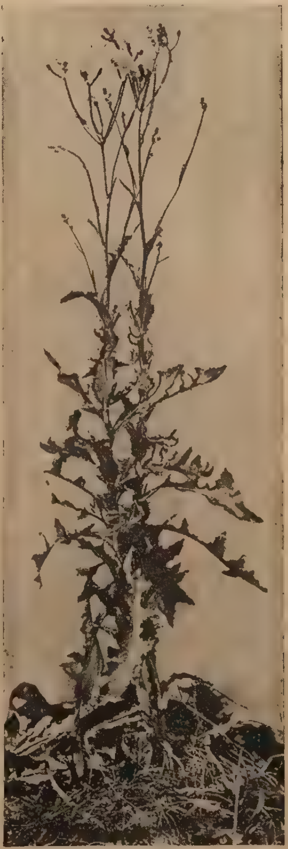

FIG. 157.—The sow-thistle which is ruining thousands of acres of productive land in the northwest and which is spreading rapidly. *What are the growth characteristics of this pest, how can it be identified, and what can be done to control or eradicate it?*

There are a number of weeds which are recognized as very troublesome over a wide territory. The number of different states in which a particular weed is listed as noxious in the seed laws of those states will be of interest in indicating the relative distribution or adaptation and the relative seriousness of infestation, considering the country as a whole. (See chapter on Seeds.) Some states have laws in which certain weeds are listed as noxious and requiring that they shall be cut at such times as will prevent the setting of seed.

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[1] Cox, H. R.—"Weeds: How to Control Them." *U. S. Dept. Agr. Farmers' Bul. 660.* 1924.

913a. *Descriptive list of over fifty of the worst weeds of the United States.*
A = Annual; B = Biennial; P = Perennial.

COMMON NAME, BOTANICAL NAME, AND DURATION OF LIFE	COLOR, SIZE, AND ARRANGEMENT OF FLOWERS	SECTIONS WHERE INJURIOUS	METHOD OF SEED DISTRIBUTION; VEGETATIVE PROPAGATION OF THE PERENNIALS	PLACE OF GROWTH AND PRODUCTS INJURED
Bermuda grass (*Capriola dactylon*), P.	Purple; 1/12 inch; spikes.	Maryland to Mo. and southward.	Seeds sparingly; rootstocks.	Fields and lawns; hoed crops.
Bindweed, field bindweed (*Convolvulus arvensis*), P.	White or pink; 1 inch; solitary.	Entire United States, especially California.	Grain and flax seeds; creeping roots.	Rich, moist soils; grain and hoed crops.
Bindweed, hedge bindweed (*Convolvulus sepium*), P.	White or rose; 2 inches; solitary.	Mississippi Valley region.	Grain and flax seeds; rootstocks.	Rich prairie and river bottoms; corn and small grains.
Bitterweed, yellow dogfennel (*Helenium tenuifolium*), A.	Yellow; ¾ inch; head.	Virginia to Kansas and southward.	Wind, hay, animals.	Meadows and pastures; injures livestock and taints milk.
Bracken, brake (*Pteridium aquilinum*), P.	No flowers.	Northwestern states and the Pacific coast.	Spores scattered by wind; running roots.	Logged-off land, meadows and pastures.
Broom-sedge (*Andropogan virginicus*), P.	Green; ¼ inch; racemes.	Mass. to Mich., Fla., and Texas.	Wind; short rootstocks, plants in tufts.	Fields and waste lands; pastures and meadows.
Buffalo-burr (*Solanum rostratum*), A.	Yellow; ½ inch; solitary.	Illinois and Colo. to Texas.	Plants rolled by wind; seeds in hay and by animals.	Fields; grain and hoed crops; wool.
Chess, cheat (*Bromus secalinus*), A.	Green; spikelets in panicles.	All grain sections.	Grain seed; especially wheat.	Everywhere; grain fields.
Chickweed, common chickweed (*Alsine media*), A.	White; ⅛ inch; cymes.	Entire United States.	Grass and clover seed; animals; has a long seeding period.	Meadows, lawns; winter crops.
Cockle-bur, clotburr (*Xanthium spp.*), A.	Green; ¼ inch; head.	Entire United States.	Carried by animals.	Cultivated fields and waste places; hoed crops and wool.
Corn cockle (*Agrostemma githago*), A.	Flowers purple, long pedunded calyc lobes long.	Central in grain growing area.	In grain seed.	Grain fields, corn.

Common Name, Botanical Name, and Duration of Life	Color, Size, and Arrangement of Flowers	Sections Where Injurious	Method of Seed Distribution; Vegetative Propagation of the Perennials	Place of Growth and Products Injured
Crabgrass (*Syntherisma sanguinale*), A.	Green; spikes.	Entire United States, especially the South.	Clover and grass seed, hay, animals.	Cultivated fields, gardens, lawns, hoed crops.
Daisy, oxeye daisy (*Chrysanthemum leucanthemum*), P.	White with yellow center; 1 inch; heads.	Maine to Virginia and Kentucky.	Clover seed, hay; woody, rather short rootstocks, but largely by seed.	Pastures, meadows, roadsides; hay, pasturage.
Dandelion (*Taraxacum officinale*), P.	Yellow; 1¼ inch; head.	Entire United States.	Wind; taproot, which spreads but little.	Lawns, meadows, waste places; hay and lawns.
Dock, yellow dock (*Rumex crispus*), P.	Green; ¼ inch; panicle.	Entire United States.	Hay and straw, clover and grass seed; taproot, which spreads but little.	Hay, small grain and hoed crops.
Dodder, alfalfa dodder, field dodder (*Cuscuta arvensis*), A.	Yellow; ⅛ inch; clusters.	All clover and alfalfa regions.	Hay, clover, and alfalfa seed.	Clover and alfalfa fields.
Dogbane, Indian-hemp (*Apocynum cannabium*), P.	Greenish white; ¼ inch; terminal clusters.	Upper Mississippi Valley.	Wind; creeping root.	Fields with sandy soil; pasture, grain and hoed crops.
Fleabane (*Erigeron ramosus*), A.	Corymbed heads; rays; white tinged with purple.	New England to Texas.	Timothy and clover seed.	Meadows and pastures.
Foxtail, yellow foxtail, pigeon grass (*Setaria glauca*), A.	Green; spikes.	Upper Mississippi Valley.	Animals, hay, grain, and grass seeds.	Land cultivated in early part of season; young grass and clover seedlings.
Garlic, field garlic (*Allium vineale*), P.	Flowers rare; umbels with bulblets.	Rhode Island to Georgia and west to Missouri.	Seeds rare; bulblets carried in wheat; underground bulbs.	Everywhere; wheat and dairy products.
Hawkweed, orange hawkweed, devils-paintbrush (*Hieracium aurantiacum*), P.	Orange; 1 inch; heads.	Maine to Ohio.	Wind, grass and clover seeds; runners similar to strawberry.	Untillable pastures and meadows.
Horsenettle (*Solanum carolinense*), P.	Purple; 1 inch; solitary.	Entire United States.	Plants rolled by wind; running roots.	Everywhere; grain and hoed crops, pastures.

913a. *Descriptive list of over fifty of the worst weeds of the United States.*—(Continued)

COMMON NAME, BOTANICAL NAME, AND DURATION OF LIFE	COLOR, SIZE, AND ARRANGEMENT OF FLOWERS	SECTIONS WHERE INJURIOUS	METHOD OF SEED DISTRIBUTION; VEGETATIVE PROPAGATION OF THE PERENNIALS	PLACE OF GROWTH AND PRODUCTS INJURED
Horseweed (*Erigeron canadensis*), A.	White; ¼ inch; heads in cymes.	Entire United States	Hay, grass, and clover seeds.	Meadows, pastures, and grain fields.
Ironweed (*Vernonia noveboracensis*), P.	Purple; ⅓ inch; heads.	Maine to Maryland and Iowa to Kansas.	Wind; short thick rootstocks, making plant grow in bunches.	Pastures and meadows.
Jimson weed (*Datura stramonium*), A.	Purple; 3 inches; solitary.	Maine to Minnesota and Texas.	Pods and plants blown by wind.	Pastures, barnyards, and waste lands; seeds, flowers, and leaves poisonous.
Johnson grass (*Holcus halepensis*), P.	Green; ⅛ inch; panicle.	Virginia to Texas and California.	In hay, grain, and grass seed; running rootstocks.	All crops except hay.
Lamb's-quarters (*Chenopodium album*), A.	Green; very small; panicle.	Entire United States.	Grain and grass seed.	Grain fields and hoed crops.
Lettuce, prickly lettuce (*Lactuca scariola*), A.	Yellow; ¼ inch; heads in panicles.	Ohio to Iowa, Utah to California.	Wind.	Everywhere; all crops.
Milkweed, common milkweed (*Asclepias syriaca*), P.	Purple; ½ inch; umbels.	New York to Minnesota.	Wind; creeping roots.	All crops and in pastures.
Morning-glory (*Ipomea hederacea*), A.	White, purple, or blue; 1½ inches; solitary.	New York to Missouri.	Corn stover, straw, and wind.	Cultivated fields, especially corn and small grain.
Mustard, wild mustard, charlock (*Brassica arvensis*), A.	Yellow; ½ inch; racemes.	Maine to Washington.	Grain, grass, clover, and rape seeds.	Small-grain fields and meadows; grains.
Night flowering catchfly (*Silene noctiflora*), A.	Large white peduncled flowers, calyc prominently veined.	Iowa, north and east.	Clover seed.	Clover and meadows.
Nutgrass, coco (*Cyperus rotundus*), P.	Brown; 1/16 inch; spikelets.	Maryland to Florida and Texas.	Wind, nursery stock, hay, and grass seed; tubers.	All soils; hoed crops.
Pennycress, Frenchweed (*Thlaspi arvense*), A.	White; ⅛ inch; racemes.	North Dakota and Minnesota.	Wind.	Grain fields and pastures; grain and dairy products.

COMMON NAME, BOTANICAL NAME, AND DURATION OF LIFE	COLOR, SIZE, AND ARRANGEMENT OF FLOWERS	SECTIONS WHERE INJURIOUS	METHOD OF SEED DISTRIBUTION; VEGETATIVE PROPAGATION OF THE PERENNIALS	PLACE OF GROWTH AND PRODUCTS INJURED
Pigweed, red root, careless weed (*Amaranthus retroflexus*), A.	Green; very small; spikes in panicles.	Entire United States.	In grain and grass seeds; plants blown by wind.	Plowed land; hoed crops.
Plantain, buckhorn, rib-grass (*Plantago lanceolata*), P.	White; 1/16 inch; spike.	Entire United States.	Hay, clover and grass seed; spreads but slowly from a crown.	Everywhere; meadows, pastures, and lawns.
Poison-ivy (*Rhus toxicodendron*), P.	Greenish white; 1/8 inch; panicles.	Entire United States.	Does not spread fast by seeds; running rootstocks.	Moist rich land, along fences; poisonous by contact.
Purslane, pusley (*Portulaca oleracea*), A.	Yellow; 1/4 inch; solitary.	Entire United States.	Tillage implements; has a long seeding period.	Rich cultivated land, especially gardens; hoed crops.
Quackgrass, witchgrass (*Agropyron repens*) P.	Green; spike	Maine to Pennsylvania and Minnesota.	Seeds of grain and coarse grasses; creeping rootstocks.	All crops on the better soils; hoed crops.
Ragweed, smaller ragweed (*Ambrosia elatior*), A.	Yellow; 1/4 inch; small heads on spikes.	Entire United States.	Wind carrying matured plants; in grain and red-clover seeds.	Everywhere, especially grain stubble; hoed crops and young grass seeding.
Russian thistle (*Salsola pestifer*), A.	Purplish; 1/4 inch; solitary.	Minnesota to Washington and southward.	Wind rolling matured plants.	Everywhere; small grain and hoed crops.
St. Johnswort (*Hypericum perforatum*), P.	Yellow; 3/4 inch; cymes.	Maine to North Carolina and Iowa.	In hay and grass seed; rootstocks.	Meadows, pastures, and waste places.
Sandbur (*Cenchrus carolinianus*), A.	Green; 1/3 inch; bur.	Maine to Florida and westward to Colorado.	Animals, especially sheep.	Sandy land pastures and waste places; pastures and wool.
Smartweed (*Polygonum pennsylvanicum*), A.	Light rose; 1/16 inch; racemes.	Maine to Minnesota, Florida, and Texas.	Wind carrying matured plants.	Moist, rich soils; hoed crops and young grass seedings.
Smartweed, marsh smartweed, devils-shoestring (*Polygonum muhlenbergii*), A.	Rose color; 1/16 inch; spikes.	Indiana to Iowa.	Wind and farm machinery; rootstocks.	Wet land, prairie, and muck soils; hoed crops, hay, pasture.

913a. Descriptive list of over fifty of the worst weeds of the United States.—(Continued)

COMMON NAME, BOTANICAL NAME, AND DURATION OF LIFE	COLOR, SIZE, AND ARRANGEMENT OF FLOWERS	SECTIONS WHERE INJURIOUS	METHOD OF SEED DISTRIBUTION; VEGETATIVE PROPAGATION OF THE PERENNIALS	PLACE OF GROWTH AND PRODUCTS INJURED
Sorrel, sheep sorrel (*Rumex acetosella*), P.	Red; ⅛ inch; panicles.	Entire United States.	In clover seed; creeping roots.	Meadows and pastures.
Sow-thistle, perennial sow-thistle (*Sonchus arvensis*), P.	Yellow; ¾ inch; heads.	Maine to Minnesota.	Wind; running rootstocks.	Grain fields and hoed crops.
Squirreltail grass, squirrel grass, foxtail, wild barley (*Hordeum jubatum*), A.	Green; spike with long bristly glumes.	Minnesota to Texas and California.	Hay, animals, wind.	Meadows and pastures; barbed seeds produce sores on live stock.
Thistle, Canada thistle (*Cirsium arvense*), P.	Purple; ¾ inch; heads.	Maine to Pennsylvania and Washington.	Wind, in hay and straw and in clover and grass seed; creeping roots.	All crops.
Thistle, common thistle, bull thistle (*Cirsium lanceolatum*), B.	Reddish purple; 1 inch; heads.	Maine to Virginia and Washington.	Wind, in alfalfa, clover, and grass seeds.	Pastures, meadows, and winter wheat.
Wild carrot (*Daucus carota*), B.	White; very small; umbels.	Maine and Virginia to the Mississippi.	In foreign clover and alfalfa seed; carried by animals and wind.	Meadows and pastures.
Wild oats (*Avena fatua*), A.	Green; panicles; similar to oats.	Wisconsin to Washington.	In seed oats.	Oat fields; awns injurious to stock.
Wintercress, yellowrocket *Barbarea vulgaris*), P.	Yellow; ¼ inch; racemes.	Maine to Virginia and westward.	In grain, clover, and grass seeds.	Grain fields, pastures, and meadows.

915. Harm That Weeds Do. Cates[2] states that considering the principal crops of the United States it is estimated that weeds reduce the yield of corn 10 per cent; the yield of tame hay 3 to 16 per cent; the yield of potatoes 6 to 10 per cent; spring grain, 12 to 15 per cent; winter grain, 5 to 9 per cent; tobacco, fruit, and truck crops from 0 to 5 per cent and pasture, 5 to 50 per cent.

916. Weeds Lower Crop Yields. The effect of the growth of weeds on the yield of corn has been indicated. (294) Call and Getty[3] state that the European bindweed reduces the yield of wheat fully one-half in the areas of infestation. They report the yield of sorghum as being 3.92 tons per acre on clean land and 2.06 tons per acre on bindweed infested soil. With later seedings of sorghum the yield was 3.54 tons on clean land and 1.92 tons on bindweed land. Sudan grass made 2.2 tons of hay per acre on clean land and 1.54 tons per acre on bindweed land.

Schafer[4] reports that this bindweed may cause practically 100 per cent loss in infested areas in Washington.

Stevens[5] states that infestation of the land with sow thistle often leaves farmers ready to abandon the land rather than attempt to eradicate it.

The reduction in crop yields which occur whenever weeds are allowed to grow in the field has been credited to several competitive effects. In fields where weeds have gotten the start of the cultivated plants, the crop is often seriously injured by the shading effect of the weed growth. Weeds use large quantities of water in their growth and in dry sections are particularly detrimental from this standpoint. Weeds are not efficient users of moisture. For each pound of dry matter produced, corn requires from 250 to 350 pounds of water and wheat from 350 to 400 pounds, while the Russian thistle requires 336 pounds; cockle-bur, 432 pounds; sunflowers, 754 pounds; lamb's-quarters, 801 pounds; ragweed, 948 pounds; and the western wheat grass, 1076 pounds. Weeds also compete with the crop for plant nutrients.

917. Reduction in the Value of the Land. Infestion with various types of weeds commonly reduces the sale value of the land and at times reduces the loans that can be obtained on it and the rental value.

918. Weeds Reduce Unit Value of Crop. Weeds may greatly reduce the market value of the crop. Pastures infested with such weeds as garlic, wild onions, and bitterweed are of great annoyance to dairymen, for when such plants are eaten by cattle a disagreeable odor and flavor is imparted to the milk and to all of the dairy products.[6]

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[2] Cates, H. R.—"The Weed Problem in American Agriculture." *U. S. Dept. Agr. Yearbook 1917*, p. 205.

[3] Call, L. E., and Getty, R. E.—"Eradication of Bindweed." *Kans. Agr. Expt. Sta. Circ. 101.* 1923.

[4] Schafer, E. G.—"The Bindweed." *Wash. Agr. Expt. Sta. Pop. Bul. 137.* 1927.

[5] Stevens, O. A.—"Sow Thistle." *N. Dak. Agr. Expt. Sta. Circ. 32.* 1926.

Cox [7] states that wheat containing garlic in considerable quantity is sold only on sample and at a price ranging from 20 to 50 per cent lower than No. 2 Red. Bread from garlicky flour, especially when eaten warm, has a pronounced odor and flavor. The money lost from wild onions or garlic alone runs into millions of dollars yearly. It has been estimated by the Chamber of Commerce of Baltimore that 60 per cent of the wheat grown in that section of the United States contains garlic. Wheat growing has been abandoned in some sections due to the presence of this weed pest.

Ayres, Hulbert, and Ahlson [8] state that 80 per cent of the alfalfa and red clover seed produced in Idaho in 1923 graded below No. 1 and thirty per cent was refused a grade and sold on sample, due to the weed seed content. They also state that Idaho farmers hauled 10,000 tons of dockage to market in 1924, largely weed seed.

919. Weeds Are Expensive to Control. The amount of cultivation necessary in many of our cultivated row crops depends altogether upon the weeds present. Infestation with quack grass, Johnson grass, Bermuda grass, Canada thistle, bindweed, and many other weeds necessarily increases very materially the number of cultivations necessary for the proper development of the crop, often necessitating hand hoeing as well as horse cultivation. At times, in the control of such weeds, the land must remain idle for a complete season, while a clean, cultivated fallow is used for the extermination of the weed.

Arny,[9] comparing different methods of eradicating quack grass, reports that the cost for the additional labor necessary for the growing of the crop on quack grass land, over that of growing identical crops under good conditions, was, in a five-year rotation, $10.10 per acre; $8.71 in a four-year rotation; $13.45 for a three-year rotation, and $8.50 for a two-year rotation. Arny reports that the expenditure of these amounts for additional labor, annually through the rotation period, resulted in the complete eradication of the quack grass.

920. Weeds Harbor Insects and Diseases. Weeds may harbor insects and diseases which attack crop plants. Cox [10] states that club root of cabbage is fostered on the wild mustard, while the Colorado potato beetle lives on nightshade and henbane. The Southern tomato wilt lives on several succulent weed plants, while in Massachusetts the corn borer is reported to carry over winter in almost any weed which may grow along the fence row. The relation between weeds and insects and diseases is further discussed in Chapters XXXVIII and XXXIX.

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[6] Pipal, F. J.—"Wild Garlic and Its Eradication." *Ind. Agr. Expt. Sta. Bul. 176.* 1914.

[7] Cox, H. R.—"Wild Onions: Methods of Eradication." *U. S. Dept. Agr. Farmers' Bul. 610.* 1914.

[8] Ayres, Jessie C., Hulbert, H. W., and Ahlson, C. B.—"Idaho Weeds; How to Know and Control Them." *Idaho Agr. Col. Ext. Bul. 65.* 1926.

[9] Arny, A. C.—"Quack Grass Eradication." *Minn. Agr. Expt. Sta.* Bul. 151. 1915.

[10] Cox, H. R.—"Weeds: How to Control Them." *U. S. Dept. Agr. Farmers' Bul. 660.* Rev. ed. 1924.

921. Weeds May Be Poisonous. Morris and Welch[11] present a chart giving the chief poisonous plants of Montana, the conditions under which found, the animals affected, the time of year they are dangerous, the part of the plant which is poisonous and the loss. The most important plants found poisonous to livestock in a large section of the country are the death camas, tall larkspur, water hemlock, lupines and loco plant.

922. The Good That Weeds Do. In many sections after continuous culture in crops for a long period of time the land is so depleted in fertility and in humus in certain cases that it will not grow profitable crops and is abandoned. Various species of weeds soon take possession of the land, occupying it fully and preventing further erosion of the soil, tying up in their tissues what plant food is in the soil and in decay releasing the plant food, which enables the succeeding crop of weeds to make still more complete use of the land. In this way weeds hold the fertility of the soil as well as the soil itself by preventing erosion and leaching and gradually build the soil up, so that after a few years of "running wild" it is a productive soil again from the standpoint of cropping.

Other benefits which have been suggested for weeds are of somewhat doubtful value. For example, it has been suggested that they are a decided benefit because they force tillage and compel crop rotation.

CONTROL OF WEEDS

A large number of different methods of weed control have been advocated and are effective for certain weeds. Some of these come under the head of prevention, while others are used for the eradication of the weed after it has once been established.

923. Use of Clean Seed. The great majority of introductions of the so-called noxious weeds come about through the use of seed crops containing these weeds. The small grains commonly contain seed of corn cockle, wild onion, ragweed, quack grass, and chess, or cheat. Perhaps one of the worst offenders in the spread of weed seed is red clover; also other small seeded forage crops. Mixtures of forage crop seed are particularly likely to contain weed seed. It is rather difficult, if not impossible, for the average man to look at seed and tell whether it is safe seed to plant. It is better to have the seed analyzed by a competent analyst who knows and can identify the various seed found. Practically all of the noxious weed seed, as well as the large majority of the common weeds, may be found in clover, alfalfa, and other small forage seed.

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[11] Morris, H. E., and Welch, Howard—"Plants Poisonous to Livestock in Montana." *Mont. Agr. Expt. Sta. Circ. 134.* 1927.

The per cent purity on the tag does not tell the desirability of the seed. Seed 99.9 per cent pure with that other 0.1 of one per cent Canada thistle should be avoided, as this could mean a seeding of 2400 Canada thistle seed per acre.

Seedsmen generally are making an effort to handle clean seed; however, there are certain seed companies with which reliable firms must compete which buy only low-grade seed and can undersell those handling good clean seed.

924. Mowing Weeds. Another means of prevention or control of weeds after they have been established on the farm is to prevent reseeding by timely mowing. The mowing machine can be used to advantage in preventing seeding of weeds in fence rows, pastures and the like. Mowing must be done before the seed pods are formed, as many weed plants have the ability of maturing seed even after being cut. Many states have laws compelling the mowing of weeds along railroads and highways. However, in many cases the mowing of such weeds is done after the seed have matured sufficiently to produce a crop next year. When properly handled this is an important means of weed control.

925. Plowing in the Control of Weeds. The effectiveness of plowing in the control of weeds varies with the type of weed and the time and depth of plowing. The time of plowing is very important. If plowing is done after the seed have become mature, the effectiveness of plowing as a means of control is very much reduced.

Goss[12] states that the depth at which seed are buried has little effect upon the preservation of their vitality. The seed of weeds or wild plants are very much more hardy or persistent than those of cultivated plants. Of many different kinds of weed seed buried at Arlington, Va., those which showed the highest germination and the fewest failures were all common and persistent weeds of the locality. Of 107 species buried in 1902, 71 species grow in 1903; 61 in 1905, after 3 years' burial; 68 after 6 years; 9 after 10 years; and 51 after 20 years. He states that any attempt to control weeds which have gone to seed by plowing them under is evidently futile.

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[12] Goss, W. L.—"The Vitality of Buried Seeds." *Jour. Agr. Res.* Vol. 29, No. 7, p. 362. Oct. 1, 1924.

Pammel and King[13] buried 72 kinds of seed. Quack grass germinated 74 per cent after 2 years and 14 per cent after 4 years. The velvet weed after a two-year period germinated 4 per cent; after 6 years, 2 per cent; after 7 years, 40 per cent; after 8 years, 34 per cent. The horse nettle germinated after 2 years, 10 per cent; 3 years, 14 per cent; 4 years, 10 per cent; 5 years, 34 per cent; 6 years, 12 per cent, and 7 years, 36 per cent.

It has been found that plowing under perennial sow thistle seed to a depth of 7 inches did not kill them, but reduced the vigor of their growth. In plowing to control weeds, the weed seed are quite commonly plowed up again when the conditions will be favorable for germination. The time of plowing is important in this respect in that early plowing may stimulate the growth of weeds which may be killed by subsequent cultivation or other operations in the preparation of the seed-bed before planting time.

926. Cultivation in the Control of Weeds. Cultivation with the harrow, cultivator, hoe, and other implements is the most effective means of control after the land has become infested. In certain cases, with persistent weeds, it is necessary to use the fallow system, in which the land is left idle but cultivated regularly to prevent any top growth, which method is necessary particularly in the case of weeds spread by underground root stalks such as the Canada thistle, quack grass, Johnson grass, perennial sow-thistle, and other noxious weeds.

In the eradication of wild morning-glory or bindweed, Stewart and Pittman[14] report that the smaller growth of root stalks and the less thrifty top growth of the plants which received frequent shallow cultivation seemed to indicate that if there was any appreciable difference between plowing and surface cutting the advantage was with the latter method. Shallow plowing seemed to be as effective as deep plowing, if not more effective.

927. Rotation of Crops in the Control of Weeds. In certain cases with the "one crop system" of farming, particularly wheat, rye, or other crops seeded solid without cultivation, the land becomes heavily infested with weeds adapted to growing with these crops. Crop rotation is effective in weed control in that cultivated crops are commonly introduced, and also because weeds adapted to one particular crop sometimes cannot meet the competition of a change of cultural methods followed in growing other crops of the rotation. Rotations may also permit the growing of crops which serve as smother crops and in this way tend to eradicate certain weeds.

[13] Pammel, L. H., and King, Charlotte M.—"Unlawful and Other Weeds of Iowa." *Iowa Agr. Col. Ext. Bul. 31.* Rev. ed. 1921.

[14] Stewart, Geo., and Pittman, D. W.—"Studies in the Eradication of Wild Morning Glory." *Jour. Amer. Soc. Agron.* Vol. 16, No. 8, p. 517. Aug., 1924.

928. The Control of Weeds by Smothering. Smothering of weeds may be resorted to in the case of small areas of certain weeds such as Canada thistle, quack grass, Johnson grass, and Bermuda grass. Smothering has been done in a variety of ways. Spreading tar paper on the ground over the infested area, or a layer of straw, has been advocated and in certain cases other materials have been used. This is not always effective, as Stewart and Pittman, cited above, report that the shoots of the morning-glory came through four feet of straw and developed many green leaves. The same general results were obtained when building paper was used as a smother. Tar paper has been effective in controlling quack grass where carefully laid with the edges of the paper overlapped and the paper extending well out over the edge of the patch of grass. Eradication by this method has been completed in six weeks of hot weather, though a longer period usually is recommended. From the standpoint of smother crops, rapid and rank growing crops such as the sorghums, Sudan grass and the millets are particularly valuable. Alfalfa has been found particularly valuable in the control of Canada thistle, while Bermuda grass also has been eradicated effectively in alfalfa fields by the application of manure and fertilizers which stimulate a rapid growth of alfalfa.

929. Pasturing to Control Weeds. Certain types of weeds may be controlled temporarily and in some cases permanently by pasturing with sheep, goats, or hogs. Stewart and Pittman[15] report a trial of the eradication of the wild morning-glory by pasturing with hogs. They found that there was a reduction in the degree of infestation to a point at which only 8 to 10 per cent of the root stalks remained, but no apparent decrease beyond this. The perennial sow thistle has been temporarily kept in check by pasturing with sheep, particularly on land where the weeds cannot be eradicated by cultivation.

Both cattle and hogs will feed on the underground root stalks of Johnson grass. Goats and sheep have been used for controlling common weeds in pastures and offer an effective means of doing this. Many of the weeds, particularly those which are classed as noxious or troublesome, are not palatable to stock and, therefore, would not be controlled by pasturing.

930. Control of Weeds by Chemicals. Common salt is the most easily obtainable chemical for weed killing. However, if applied sufficiently strong to kill the weed plants, it kills all other vegetation in the area and remains in the soil for some time, preventing all plant growth. Various types of petroleum oils and waste oils from garages and other sources are excellent weed killers, but, like common salt, kill all vegetation. Iron sulphate solutions, with from 1¾ to 2 pounds of iron sulphate per gallon of water, applied at the rate of 50 to 75 gallons per acre, has been used widely in weed control. It does not seriously injure grass.

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[15] *Ibid.*, p. 518.

Olive[16] reports that iron sulphate entirely killed wild mustard, peppergrass, pigweed, sweet clover, and badly injured Russian thistle, sunflowers, dandelion, dock, thistle, white clover, red clover, and alfalfa. It but slightly injured plantain, sheep sorrel, prairie rose, lambs quarter, and was not injurious to small grains or corn.

In spraying a field of 300 acres, the acre cost for material has been estimated at $1.25.

Call and Getty[17] (Kansas) applied salt in the control of bindweed. Soil which received 28 tons of salt had no bindweed left; 15 per cent of the bindweed were left on the 16-ton plot and 75 per cent on the 8-ton plot. The soil receiving salt assumed a whitish color and a sticky structure like gumbo and was unproductive. They state that in western Kansas there are areas salted ten or more years ago which are still bare or are growing only Russian thistles.

Lathshaw and Zahnley[18] report that sodium chlorate applied as a spray was found the most effective and economical method of killing the European bindweed or wild morning glory. Sodium chlorate is not poisonous and will not injure the soil. One hundred pounds of sodium chlorate dissolved in 100 gallons of water is applied at the rate of 100 gallons per acre. Usually two or three applications are necessary for eradication. This material has also been used successfully in the eradication of Canada thistle and quack grass.

Sodium chlorate is as injurious to other growing plants as it is to the bindweed. There is some danger from fire in the use of this material for when dry and mixed with fine material it ignites readily.

Hansen[19] reports that when dodder is first introduced into a section it is usually in small, scattered areas. Such areas should be mowed before the seed mature, or else sprayed and burned. If the seed has formed, burning is the only remedy.

931. Control of Annuals and Biennials. Annual weeds produce seed only once before they die, and are propagated only by seed. Control measures for this type of weed consist of (1) preventing the introduction of this seed onto the farm, and (2) preventing the production of seed after introduction. Cultivation is the most common method of control. Annual weeds ordinarily offer little trouble in regard to control, though in some cases the seed are very persistent and may carry over in the soil through a period of years.

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[16] Olive, E. W.—"The Killing of Mustard and Other Noxious Weeds in Grain Fields by the Use of Iron Sulphate." *S. Dak. Agr. Expt. Sta. Bul. 112.* 1909.

[17] Call, L. E., and Getty, R. E.—"The Eradication of Bindweed." *Kans. Agr. Expt. Sta. Circ. 101.* 1923.

[18] Latshaw, W. L., and Zahnley, J. W.—"Killing Field Bindweed with Sodium Chlorate." *Kans. Agr. Expt. Sta. Circ. 136.* 1928.

[19] Hansen, A. A.—"Dodder." *U. S. Dept. Agr. Farmers' Bul. 1161.* 1921.

Biennial weeds store up food material in the roots the first season and produce seed the second season. The same general methods as recommended for annual weeds are recommended for the control of biennials, though in some cases biennial plants, when plowed in the fall, will grow from the root the next spring and so require thorough spring cultivation.

Both annual and biennial weeds when cut persist in making new growth and unless watched closely will make seed before frost. If not killed by cultivation it may be necessary to cut three or four times.

932. Control of Perennials. Perennials which are propagated both by seed and by underground stems or root-stalks are the difficult types to eradicate. Outstanding weeds of this class are Canada thistle, Johnson grass, horse nettle, quack grass, perennial sow thistle and European bindweed. With this type of plant, preventing seeding will not stop the spread of the plant. The root-stalks have the ability of sending up new shoots and ordinary cultivation only tends to spread the plants as a small section of root will establish a new center of infestation. In large areas the principal means of eradication are (a) frequent and persistent cultivation preventing all top growth and (b) the use of chemicals. By frequent cultivation the underground root stalks are sapped of their strength and when continued will completely eradicate the plant. It is important that the plant be given no opportunity to make any extended top growth, as when a top growth is made the plant builds up the depleted root stalk by the storage of food material in it. On a large scale the use of a smother crop is sometimes effective as a means of control, while on small areas it may sometimes be desirable to remove the plants or to cover with tar paper or some other impervious layer.

In the control of bulbous perennials such as the wild onion and the wild garlic, several difficulties are encountered, for the wild onion produces aërial bulbs or bulblets as well as basal bulblets. The basal bulblets are of two sorts, commonly called hard and soft bulblets. The soft ones start growth in the fall, while the hard ones delay development until the following spring. It is because of this range in method of reproduction that the wild garlic or wild onion is so persistent.[20]

In an attempt to eradicate some of our particularly noxious weeds which are spread both by seed and root stalks a community effort is necessary, due to the ease with which the weeds can be carried from one farm to another.

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[20] Cox, H. R.—"Wild Onion: Methods of Eradication." *U. S. Dept. Agr. Farmers' Bul. 610.* 1914.

STUDY QUESTIONS ON CHAPTER XXXVII

1. List in order of importance the worst weeds of your section. Indicate those declared noxious according to your state law.
2. List in order of importance the harm that weeds do. Give an example of a weed causing each loss which you list. Preferably list weeds which grow in your own locality.
3. In what crop seed are bad weeds most likely to be introduced into your locality? Explain.
4. List in order of importance the methods by which weeds may be introduced or spread in your section.
5. Considering the weeds common in your section, what methods would you recommend for the control of weeds in pastures and on roadsides.
6. Outline a method of weed control for a farmer having a few patches of the worst perennial weed of your section and a thorough infestation with the common weeds. Your recommendation, carefully carried out, should result in the control of all common weeds and the eradication of the noxious weed.

APPLICATION ASSIGNMENTS ON CHAPTER XXXVII

1. You have the choice of two farms about equal in fertility and value except that one is heavily infested with quack grass. Both farms are located in southern Minnesota. The farm without the quack grass can be bought for $135 per acre and the one with quack for $105. Which will you buy? Explain.
2. You have the choice of two farms equally rich and of equal value except that one is relatively clean while the second is infested with dock, cockleburr, sheep sorrel, Indian mallow, ragweed, foxtail and other similar weeds. You can buy the first farm for $175 per acre and the second for $160. Which do you consider the better buy? Explain.
3. The board of supervisors wish to set a time for the mowing of roadsides in order to control weeds. They ask your recommendation on the best time or times to mow. Write your answer, stating specifically the reasons for the date or dates you suggest.
4. You have a 10-acre field badly infested with Canada thistle. You plan to eradicate the thistle, either by the use of chemicals or by fallowing. What considerations will influence your decision? What will you do?
5. You have a field heavily infested with dock and want to plow to kill it out. When would plowing be most effective? Why?

CHAPTER XXXVIII

INSECT PESTS

The number of different species of insects has been estimated at 600,000, and the loss of various crops at from 5 to 10 per cent of their total value, thus making the losses caused by insects enormous. It has been estimated that annual losses from insects total nearly two billion of dollars, without including direct losses to humans from disease nor costs in controlling insects.

It is estimated that about half of our worst insect pests have been imported into this country, most of them coming from Europe. From the standpoint of farm crops, some of the most important pests brought in accidentally are the European corn borer, the Hessian fly, the cotton boll weevil, the pink boll worm, the sugar cane borer, the alfalfa weevil, the pea weevil, and the angoumois grain moth. In some cases insects, in addition to causing direct loss, may carry diseases to plants; the aphids carry mosaic to the potato, sugar cane, and tobacco; the leaf hoppers carry the curly leaf of beets and the Colorado potato beetles carry the wilt of the potato.

933. General Methods of Controlling Insects. The control of insect pests is partially effected by natural means. When a particular insect becomes very numerous further development is checked by its natural enemies such as birds, parasitic insects, diseases, and unfavorable food or climatic conditions. This control, however, may not effect any noticeable reduction until after serious losses have been suffered as a result of crop damage. Other methods of control have to do with the prevention of breeding and hibernation, mechanical destruction by means of cleaning up trash, plowing and rotation of crops. Losses are sometimes reduced by regulating the time of planting and the method of growing the crop and by using resistant varieties. The insects are often destroyed in large numbers by trapping them in certain stages of development and by the use of insecticides.

Insecticides for insect destruction are of three types, used with reference to the habit and nature of the insect. (1) Poisons such as arsenicals, Paris green, hellebore, etc., are used for biting or eating insects, in various mixtures as dusts, or liquids. (2) Poisons and other contact substances such as tobacco extracts, soaps, oils, emulsions, lime sulphur and various dusts are used in the control of sucking insects. (3) Gases such as carbon bisulphide, hydrocyanic acid gas, paradichlorobenzene, and calcium cyanide are used for either biting or sucking insects.

934. Some Important Insects and Methods of Combating Them. The insects which have caused the most damage to the corn, wheat, sorghum, and cotton crops, or promise to be the most destructive are the Hessian fly, the chinch bug, the cotton boll weevil, and the European corn borer. Very brief information on these insects follows, but the student will want also to consult special publications dealing with these pests.

935. The Hessian Fly. "The parent fly is a small gnat somewhat resembling a mosquito. Its two wings are covered with minute hairs, giving them a distinctly dusky appearance. . . . They are feeble fliers, but are carried by air currents and moderate winds for comparatively long distances.

"There are two main broods of the Hessian fly during the year. The mature insects are found, and frequently in immense numbers, in wheat fields during the last few days of August and in September and then again during April and May. . . . The eggs are generally placed in rows of from two to a dozen, in the grooves of the upper surface of the leaves. . . . Most of the eggs are deposited shortly after the female emerges from the 'flax-seed' stage. After an incubation period of from 4 to 14 days, depending upon the weather conditions, the eggs hatch and the tiny reddish colored larvae or maggots move down the upper surface of the leaf, reaching the leaf sheath beneath, where they finally come to rest at or near the node. . . . In three or four weeks the maggot completes its growth, and changes into an object resembling a 'flax-seed,' from which it derives its name. Within this covering (the flax-seed stage) the fall brood passes the winter and the spring brood the summer. Following this, depending again upon the time of year and weather conditions, the larvae moult and transform into the pupal stage. As the time for emergence approaches the pupa works its way out through one end of the flax-seed (puparium) and then continues its journey upwards. . . . Upon reaching a favorable location the adult fly breaks forth and becomes ready for flight in a remarkably short time."[1]

Wheat fields are injured in the fall by the larva sucking the sap and the plants often die. In the spring the larva attacks the tillers which escaped in the fall, so weakening them that many break over. The Hessian fly prefers wheat but will live on rye, barley, emmer, spelt, and a few of the grasses.

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[1] Drake, C. J., Fenton, F. A., and Butcher, F. D.—"Hessian Fly Control in Iowa." *Ia. Agr. Expt. Sta. Circ.* 86. 1923.

Control. The chief and easiest method of control is to delay the seeding of fall wheat so that the plants will not be up until after the adults have emerged and the egg-laying time has passed. The adult fly dies in a short time after emerging and damage is not severe if seeding is delayed in this manner. Volunteer wheat should be destroyed and in certain cases stubble may be burned or plowed under.[2] This method of control has proved very effective.

936. The Chinch Bug. The chinch bug passes the winter as an adult. The adult chinch bug is about one-fifth of an inch in length with a black body and white wings marked by a small black triangle on their outer margins. There are two forms, a short-winged form in the East and a long-winged one which is generally distributed. The adults hide over winter in bunches of grass or other rubbish in or near the fields. Small red eggs are deposited near the surface of the ground on grass plants. Red nymphs are produced from the eggs. After 30 or 40 days' growth, during which time several moults have occurred, the bugs acquire wings. In the northeast portion of the United States there is but one generation, while in other sections there are two.

The worst injury from the chinch bug is to small grains and corn in the Central and North Central states, though it also feeds upon the sorghums and millets and other grass plants. The chinch bug damages the plant by sucking the sap.

Control. Many chinch bugs may be destroyed by burning trash. Cleaning up fence rows and grass lands is the most important step in this control. The chinch bug breeds early in the season in small grain fields and migrates by crawling to neighboring corn fields when the small grain is harvested. This migration may be checked and the corn protected by barriers between the corn and the small grain. Barriers are made in various ways, as for example by throwing up a sharp ridge with a furrow on the side toward the small grain field and with frequent holes into which the bugs fall where they are destroyed. Under certain conditions a combination coal-tar and calcium cyanide barrier has been found effective. Dust barriers have been advocated but they are difficult to maintain, particularly when it rains. Crop rotations that avoid grass crops have also been helpful.[3]

Certain strains of corn, notably the Champion White Pearl, Black Hawk, Mohawk, and Golden Beauty, have been found somewhat resistant to damage by chinch bugs in Illinois.[4]

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[2] McColloch, J. W.—"The Hessian Fly in Kansas." *Kans. Agr. Expt. Sta Tech. Bul. 11.* 1923.

[3] Flint, W. P., *et al.*—"The Chinch Bug and How to Fight It." *U. S. Dept. Agr. Farmers' Bul. 1498.* 1926.

[4] Flint, W. P., and Hackleman, J. C.—"Corn Varieties for Chinch Bug Infested Areas." *Ill. Agr. Expt. Sta. Bul. 243.* 1923.

937. Cotton Boll Weevil. The cotton boll weevil lives over winter in the adult beetle form, hibernating in fields and buildings, or in moss or other trash in the woods. It emerges over a rather wide range of dates in the spring and feeds on the tender buds of the cotton plant. When squares appear the weevil punctures these and deposits its eggs within them. The adult is a snout beetle about one-eighth to one-third of an inch in length including the snout, and is grayish or yellowish to almost black in color. The eggs hatch usually in 3 or 4 days. The larva is a white, strongly curved grub, from one-fifth to two-fifths of an inch long, with a brown head and is wrinkled across the back. The developing larva remains in the square which usually falls about the time the larva has reached the pupa stage. The adult emerges in 3 to 5 days, and is soon ready to start the cycle over again by depositing eggs in other squares. From 2 to 8 generations are possible in a season, as in hot weather only 15 to 20 days are required for the cycle. The eggs for the later generations are deposited in the green cotton bolls. Cotton is the chief food plant of the boll weevil.[5]

Control. Control measures for the cotton boll weevil are strongly diversified. The extensive use of fertilizers and the growing of early varieties of cotton so as to hasten the crop to maturity are important means of control. Early in the spring the tips of the young plants may be covered with calcium arsenate as a dust or sirup in heavily infested fields. Later poisoning with calcium arsenate dust or other substances has been tried with fair success. Cleaning up and destroying trash and crop refuse is also advocated as a means of control.[6]

All means of control are most effective in dry seasons.

938. The European Corn Borer. This insect passes the winter as a full grown larva about one inch long. The larva is dirty white or pinkish in color with a dark brown or black head and brownish dots along the sides of its sparsely hairy body. Larvæ are found in burrows in the corn stalks, stubble, and cobs, or in the stems of other food plants. In late April or May, the larvæ becomes a pupa within the burrow and two or three weeks later the moth emerges. The female is a small yellowish moth with a wing expanse of from three-fifths to slightly over one inch. The fore wings are marked with reddish zigzag lines and wide reddish areas along each outer margin; the rear wings are paler than the others. The moth soon lays its eggs in clusters of 15 to 20 on the under side of the leaves and on the stalks. The eggs hatch in from 4 to 12 days and the larva feeds on the green plant, becoming mature in certain sections in 35 to 40 days; two generations occur per season in Massachusetts and one in other sections of infestation in the United States.

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[5] Hunter, W. D., and Coad, B. R.—"The Boll Weevil Problem." *U. S. Dept. Agr. Farmers' Bul. 1329* 1923.

[6] Hunter, W. D.—"The Boll Weevil Problem." *U. S. Dept. Agr. Farmers' Bul. 848*. 1917.

The European corn borer appears to prefer corn but breeds or feeds also on a great variety of crop plants and weeds. It has been found feeding on 200 kinds of plants.

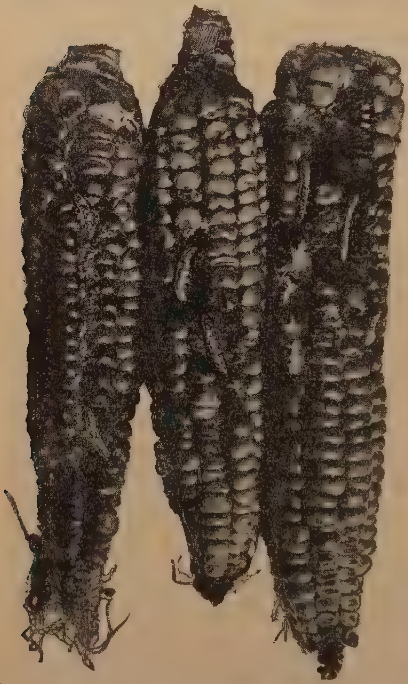

FIG. 158.—Sweet corn ears ruined by the European corn borer. In certain regions, where a few years ago corn was the most important crop grown, the activities of the corn borer have been such as practically to exclude corn from the rotation. *What changes may be expected in crop production practices in the central corn belt as the losses from corn borer damage increase?*

Control. Control measures for the corn borer have not been worked out completely. Putting the corn crop in the silo, the thorough destruction of all waste plant materials in corn fields, including corn stalks, cobs, stubble, and weeds, and the late planting of corn have been recommended. Rubbish is destroyed by burning or by thorough deep plowing. The introduction and multiplication of parasitic pests may aid somewhat in the control of the corn borer. All measures in use at present are for the purpose of checking the spread and reducing the damage in so far as possible. It is evident that the borer will spread and continue to be a serious menace to the corn crop.[7]

939. Thirty-five of the More Important Insects. An effort has been made to select thirty-five of the insects which have caused the most serious losses to field crops, and to present in tabular form, very brief information on appearance, distribution, damage and control. As in all other parts of this work the authors have attempted only to summarize as accurately as possible some of the best material available from various sources. In the preparation of the material which follows particular credit should be given to the recent work of Metcalf and Flint[8] and to various publications from the United States Department of Agriculture.

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[7] Worthley, L. H., and Coffrey, D. J.—"Scouting, Quarantine, and Control for the European Corn Borer. 1917-1926." *U. S. Dept. Agr. Tech. Bul. 53.* 1926.

[8] Metcalf, C. L., and Flint, W. I.—*Destructive and Useful Insects: Their Habits and Control.* McGraw-Hill Book Company. New York. 1928.

939a. Digest of information on thirty-five of the more important insects damaging crop plants.

	ADULT	LARVA	DAMAGE	CONTROL	DISTRIBUTION	CROPS ATTACKED IN ORDER OF IMPORTANCE
White grub	June Bug or May Beetle. Heavy, robust, yellow to brown, beetle ½ in. long.	Grub worm. White, soft, stout, brown headed worm. Curls up.	Grubs eat roots. Beetles eat foliage of trees.	Rotation of crops, pasturing with hogs, fall plow. Avoid sod with susceptible crops.	General damage severe in N. E. U. S.	Corn, potatoes, strawberries, grass.
Wire worm	Click beetle. Flat, slender, brown beetle, ⅓ in. long.	Hard, cylindrical. Yellowish brown, from ½ to 1½ in. long.	Worms eat seed and stem below ground.	Avoid putting susceptible crops on sod land. Plow early. Crop rotation.	General U. S. Wet land.	Corn, wheat, oats.
European corn borer	Yellowish brown moth. Wing spread ¾ in.; lined and bordered with reddish brown.	Dirty white or pinkish worm; 1 in. long. Brown dots along each side.	Bores into stalk ear; eats kernels. Causes breakage.	Destroy stubble, ensile or shred stover. Destroy weeds.	New England, N. Y., Pa., O., Mich., Eastern Canada.	Corn, sorghum, thick stemmed vegetables, and weeds.
Corn bill bug	Black, dirty coated; ½ in. long with a snout.	Whitish grub. Brown head; ½ in. long.	Feeds on young corn; punctures rolled leaves, making row of holes. Larva bores in stem at base.	Fall plow. Rotate crops. Deep plowing.	East and south U. S.	Corn, rice, chufas, peanuts.
Southern corn root worm	Beetle yellowish green; twelve black spots on wing covers; ¼ in. long.	Slender, yellowish white worm. Brown head. About ½ in. long.	Bores into stem and feeds on roots. Plants lodge.	Plant very late.	Eastern half U. S.	Corn, small grains, grasses, cucumbers.
Northern corn root worm	Green beetle; ⅕ in. long.	Round, slender worm, ⅖ in. long. White with brown head.	Tunnels in roots. Eats roots off.	Crop rotation.	Corn belt and central Great Plains.	Corn only.
Corn root louse	Aphid blue green, round, winged or wingless.	Nymph.	Sucks juice from roots.	Crop rotation. Plow to break up ant colonies.	Corn and cotton belts.	Corn, cotton, several weeds, and grasses.

939a. *Digest of information on thirty-five of the more important insects damaging crop plants.*—(Continued)

	ADULT	LARVA	DAMAGE	CONTROL	DISTRIBUTION	CROPS ATTACKED IN ORDER OF IMPORTANCE
Larger corn stalkborer	Moth. White to smoky yellow; 1¼ in. wing spread. At rest wings held close, making acute triangle.	Thick, dirty white caterpillar. Covered with many dark spots. 1 in. long.	Eats unfolding leaves, then bores into base of stalk.	Crop rotation. Destroy stubble.	Cotton belt.	Corn.
Cutworm (several species)	Moth. Wing spread 1½ in. Vary in color with species.	Caterpillar. Pale brownish to grayish white worms. Vary with species.	Cuts plant off near ground.	Poison bait rotate crops.	General. Particularly damaging in North.	Grains, grasses, etc.
Corn ear worm	Moth. Yellowish green or drab. Wing expanse of 1⅗ in.	Caterpillar Varies. from green to almost black. Striped. 2 in. long.	Cuts through husks; eats and tunnels through kernels.	Sweet corn silks dusted with calcium arsenate helps.	General U. S. Particularly cotton belt.	Corn, cotton, tomato, tobacco, and many others.
Fall army worm	Moth. Gray, white or dull colored. 1¼ in. wing expanse.	Caterpillar, green to black with inverted white Y on head. 1½ in. long.	Eats foliage; often completely destroying crop or pasture.	When feeding and marching. Poison bran mash. Spray infected spots.	Most of eastern and southern U. S.	Corn and grasses, tobacco and most plants.
Army worm	Moth. Brownish gray; 1½ in. wing expanse.	Caterpillar. Greenish; 3 stripes on side. 1½ in. long.	Eats foliage, stripping field.	Barriers when marching. Poison bran mash.	General U. S.	Corn, grasses and many other plants when hungry.
Grasshoppers	Grasshopper (several species).	Nymph.	Eats foliage, stripping plants.	Cultivation to destroy eggs. Poison bait.	General U. S.	Corn, small grains, alfalfa, all crops.
Hessian fly	Mosquito like fly. Dark bodied; ⅒ in. long.	Greenish white maggot. ⅛ in. long.	Larva sucks juices from plants. Weakens stems. Causes lodging.	Delay seeding until flies have emerged.	All wheat areas in U. S.	Wheat, barley, rye and some grasses.
Chinch bug	Soft bodied bug. Black with white wings with spot on them. ⅕ in. long.	Nymph.	Sucks juices from plants.	Destroy trash; prevent migration from grain field by barriers.	General U. S.	Corn, small grains, grasses.

	ADULT	LARVA	DAMAGE	CONTROL	DISTRIBUTION	CROPS ATTACKED IN ORDER OF IMPORTANCE
Wheat joint-worm	Wasp-like insect. Black. ⅙ in. long.	Larva. Yellowish white. ⅙ in. long.	Stems near nodes causes knots, and weak straw.	Burn stubble.	East of Great Plains.	Wheat.
Green bug	Yellowish green aphid.	Nymph.	Suck sap. Weakening and killing plant.	Destroy volunteer grain in south.	General U. S., damage mostly south.	Small grains, corn, grasses.
Wheat stem sawfly	Black, wasp-like insect. Yellow banded abdomen. ½ in. long.	Worm. Yellowish white; ½ in. long.	Bores into tunnels down stalk. Straw breaks.	Plow stubble deep. Rotation of crops.	Northern and western wheat belts.	Sp. wheat, rye, durum, spelt, barley.
Alfalfa weevil	Oval, brown snout weevil; 3/16 in. long.	Green, black headed worm. ¼ in. long.	Adult eats stems and leaves. Larva feeds on leaf buds.	Spray or dust with calcium arsenate.	Rocky Mt. states. Western Great Plains.	Alfalfa.
Alfalfa caterpillar	Orange yellow moth. 2 in. wing spread.	Dark green caterpillar. White and red stripes on sides. 1¼ in. long.	Strips plants of leaves.	Dust with calcium arsenate. Cut early.	General U. S., damaging in southwest.	Alfalfa, perhaps other legumes.
Alfalfa web-worm	Buff to brown moth. ¾ in. wing expanse.	Greenish brown; 3 black dots in each segment on each side; ¾ in. long.	Webs tops of plants together. Devours leaves.	Brush—drag alfalfa or cut for hay.	General U. S.	Alfalfa, cotton, corn, vegetables.
Bean weevil	Brownish gray beetle. ⅛ in. long.	Stout, wrinkled white larva. ⅛ in. long.	Grubs burrow inside bean.	Plant weevil free beans. Protect in storage.	General U. S.	Beans, cowpeas
Pea weevil	Grayish brown; ⅕ in. long.	Stout, white grub with brown to black head.	Works on inside of peas.	Plant free seed.	General; more in east and south.	Peas
Cowpea weevil	Reddish brown beetle with 2 ivory-like lobes at base of thorax.	Fleshy grub, yellowish white in color.	Feeds on inside of cowpea seed.	Fumigation as for rice weevil.	Cotton belt.	Cowpeas, other legumes.

939a. *Digest of information on thirty-five of the more important insects damaging crop plants.*—(Continued)

	ADULT	LARVA	DAMAGE	CONTROL	DISTRIBUTION	CROPS ATTACKED IN ORDER OF IMPORTANCE
Cotton boll weevil	Snout beetle. Yellowish to almost black. ¼ in. long.	White grub. Wrinkled, curved, brown head, ¼ in. long.	Grubs feed inside squares or bolls.	Dust with calcium arsenate. Clean up trash. Grow early crops.	Cotton belt except northern and western border.	Cotton.
Pink boll worm	Dark brown moth. ¾ in. wing expanse.	Round, white larva with pink dorsal side, ½ in. long.	Larva feeds on flowers and young bolls and seed.	Quarantine, destroy infected bolls, fumigate seed or kill by heat.	Restricted areas in S. W. cotton belt.	Cotton, okra, hollyhock, hemp.
Cotton boll worm	Corn ear worm.	Corn ear worm.	Eats bolls and squares.	Deep plowing, trap crop of corn.	Corn and cotton belts.	Corn, cotton, tomato, tobacco, and many others.
Tobacco flea-beetle	Brownish beetle. Dark band on wing. 1/20 in. long.	Slender dirty white worm. ⅛ in. long.	Feeds on foliage in seed bed and in field.	Destroy weed in vicinity of seedbed. Use Paris green and lead arsenate dust in field.	General in tobacco sections.	Tobacco, tomato, potato, several weeds.
Tobacco hornworm	Narrow winged moth. Bright orange spots on abdomen. 4½ in. wing expanse.	Caterpillar. Stout, green, and has a horn-like projection.	Eats leaves, leaving only midrib.	Arsenate of lead dust; hand picking.	General U. S.	Tobacco, tomato, egg-plant, pepper.
Colorado potato beetle	Stout yellow beetle. Black striped wing covers. ⅖ in. long.	Larva soft reddish color with black spots on sides.	Larva and adult eat foliage.	Spray or dust Paris green or arsenate of lead or calcium arsenate.	General U. S.	Potatoes, tomatoes, egg-plants. Tobacco.
Potato aphid	Often winged. Pink or green colored; ⅙ in. long.	Nymph.	Sucksap. Spread mosaic.	Spray-nicotine sulphate.	General U. S.	Potato, tomato, roses.
Apple leaf-hopper	Yellowish green winged. ⅛ in. long.	Light colored nymph.	Leaf burns and falls.	Bordeaux 4-6-50.	North Central states - areas in other sections.	Potato, apple, beans, alfalfa, beets.
Rice weevil	Black snouted beetle. Dull reddish brown. ⅛ in. long.	Short, fat, whitish larva, ⅛ in. long.	Adults and larva eat grain. Flies to field.	Fumigate seed. Heat between 122 to 140.	General U. S.	Cereal grains.

	ADULT	LARVA	DAMAGE	CONTROL	DISTRIBUTION	CROPS ATTACKED IN ORDER OF IMPORTANCE
Granary weevil	Chestnut brown beetle, similar to rice weevil; ⅙ in. long.	Similar to rice weevil.	Similar to rice weevil. Cannot fly.	Fumigate seed. Heat between 122 to 140.	General U. S.	Cereal grains.
Angoumois grain moth	Grayish moth. ½ in. wing expanse.	White larva with brown head. ⅕ in. long.	Feeds in grain in storage. Infests in field and bin.	Fumigate seed. Heat between 122 to 140.	General U. S.	Cereal grains.

IMPORTANT PRACTICES AND METHODS IN COMBATING INSECTS

There are certain well-known practices and methods which may be used effectively against a very large number of different insects which make war on field crops. A number of the more important of these include plowing and cultivation, pasturing, rotation and selection of crops, and the destruction of infested material and of material affording hibernation.

940. Tillage and Pasturing. In the control of insect pests the time and depth of plowing may be important. If insects pass the winter near the surface of the ground, deep plowing may crush and kill them or bury them so deep that they are unable to get to the surface in the spring. Some insects in burrows, in the pupal stage, are brought to the surface by fall plowing and are subsequently killed by cold weather or perhaps destroyed by birds and rodents.

Certain grubs are eaten by hogs in pasturing a field, and while not a method generally practical to use, it may serve to prevent serious damage in limited areas.

941. Rotation and Selection of Crops. Perhaps one of the most effective methods of lowering the damage done by a particular insect pest is to select crops not seriously attacked and to arrange the sequence of crops so that the life cycle of the pest is interrupted. The continuous growing of a crop badly attacked by a pest is greatly to the advantage of the insect. Certain insects may be effectively controlled by the introduction into the rotation of a crop not attacked, and all insects are checked in their development by such a practice. In certain cases such heavy infestations may result from the continuous and general growing of a crop that it becomes necessary to discontinue the growing of that crop completely until the pest is under control. Community effort in the control of insects is often necessary, as one field may serve as a breeding ground from which the pest will migrate and reinfest adjoining farms.

An important consideration in areas infested with certain insects is the sequence in which the crops are grown on the land. For example, in northeastern Iowa corn has been almost completely destroyed by the white grub in certain years when grown on sod land. It has been possible for the entomologists to foretell the grub years and advice has been given in advance so that farmers could avoid plowing sod and planting to corn in these particular years.

942. Planting Dates. In the case of certain insects, such as the Hessian fly, prevention of serious damage may easily be avoided by delaying the seeding until after the adults have emerged and the egg-laying time has passed. In the boll weevil area everything is done to get an early crop of bolls set before the weevils are present in large numbers. There are indications that late planted corn is less seriously damaged by the European corn borer than early planted corn.

943. Destruction of Trash. Many insects hibernate or spend a portion of their life cycle in plant residues, grassy fence rows, and weed patches. It is often advisable to destroy these sources of infestation by burning or by thorough deep plowing. The clean-up campaign in areas infested by the European corn borer is a good example of this. In chinch bug areas the destruction of grassy and weedy areas by fire has often been advocated.

944. Quarantine Areas. When there is danger of insects being moved or brought into new territory, quarantine is often used. Quarantine areas are commonly established by the Federal Government. The two principal ones from the standpoint of crops are the European corn borer quarantine and the quarantine for the pink boll worm of cotton. Products likely to aid in the spread of the insect concerned are prevented from being taken out of the infested area.

945. Parasitic Enemies. Destruction by the introduction and breeding of parasitic enemies of the pest are being used in the control of certain insects. This method has proved particularly effective in the control of some insects and is receiving further study by entomologists.

946. Poison Baits. The use of poison baits has been very effective in certain sections in the control of grasshoppers and army worms[9] and sometimes cutworms. The bait is spread in the feeding area in the early morning or late in the evening so that it does not dry out and lose its attraction for the pests. The poison bran bait[10] may be made by mixing 1 pound of Paris green, of sodium arsenite or of white arsenic and 25 pounds of bran with enough water to make it crumbly. The addition of cheap molasses made bait more attractive for grasshoppers where sodium arsenite was the poison but it did not have this effect with white arsenic.[11] Calcium chloride, at the rate of 5 pounds for 50 pounds of mash, is added where the mixture may dry out too rapidly.

947. Control of Insects in Stored Grain.[12] Infestations with weevil or angoumois moths in seed are common. There are several substances used which produce a gas and kill the insects; these do not kill the eggs, however, and a second treatment is needed.

[9] Walton, W. R., and Luginbill, P.—"The Fall Army Worm or 'Grass Worm' and Its Control." *U. S. Dept. Agr. Farmers' Bul. 752.* 1916.

[10] Corkins, C. L.—"Sodium Arsenite as a Killing Agent in Grasshopper Baits." *Colo. Agr. Expt. Sta. Bul. 280.* 1923.

[11] Swenk, M. H.—"Further Experiments with Poisoned Baits for Grasshoppers." *Nebr. Agr. Expt. Sta. Res. Bul. 41*, p. 44. 1927.

[12] Back, E. A., and Cotton, R. T.—"Control of Insect Pests in Stored Grain." *U. S. Dept. Agr. Farmers' Bul. 1483.* 1926.

Carbon disulphide placed in a shallow pan on top of grain in a tight container kills adult insects and larvæ by forming a poisonous gas heavier than air. From 3 to 5 pounds of the liquid per 100 bushels of grain are required. Care must be used in handling carbon disulphide as it is deadly to all animal life and is inflammable. It does not work well at low temperatures. The treatment must be repeated in order to kill the larvæ from the eggs.

Paradichlorobenzene is now commonly used as a control for grain insects. It can be purchased in crystalline form and a heaping teaspoonful per bushel will give protection if the grain is stored in an airtight container. The crystals vaporize slowly and treatment is extended over a considerable time. It is used extensively in preserving small quantities of seed in laboratories.

Heat is often used and is the most effective means where it can be controlled. A temperature of 130° F. for 30 minutes will kill adults, larvæ, and eggs of all common grain insects without injury to the germination of the seed when the grain contains not over 13 per cent of moisture.

In regions where the temperature falls as low as —20° F. grain insects may be killed by the simple expedient of allowing the temperature in grain storage buildings to go as low as possible.

STUDY QUESTIONS ON CHAPTER XXXVIII

1. List in order of importance the insect pests attacking field crops in your section.
2. What are the conditions which make the control of the cotton boll weevil and the European corn borer so difficult?
3. List the methods of control recommended for each of the more important insect pests of your section.

APPLICATION ASSIGNMENTS ON CHAPTER XXXVIII

1. In the spring your winter wheat appears weakened, the heads are light and many of the plants fall over. What pest do you suspect? Why?
2. At wheat harvest the corn nearest the wheat begins to die. What pest do you suspect? Why? What will you do?
3. Your sweet corn ears are tunneled around the tips and damaged severely. What is responsible? What will you do?
4. At tasseling time you note broken tassels and sawdust-like castings in your corn. What do you suspect? What will you do?
5. Your corn falls over and you see brown ants swarming over the stalks What do you suspect? What can you do?
6. Your corn, on rich sod ground, turns yellow and dies. On examination the plants are found to be practically without roots. What is the trouble? What can you do?

7. In your corn field you notice that many plants are cut off, particularly in the outside rows near grass land. What causes this? What can you do?
8. All green material is eaten out of the cotton leaves across one side of your field. The strip is larger each day. What causes this? What can you do?
9. Your cotton continues to shed the squares as they form and you note that each square has been punctured. In many of these squares a tiny worm is found. What is the cause and the remedy?

CHAPTER XXXIX

PLANT DISEASES

The loss in various crops due to all diseases has been estimated each year from 1919 to 1925, inclusive. The extremes for each crop[1] during the period are as follows:

CROP	HIGHEST LOSS	LOWEST LOSS	PRINCIPAL DISEASES IN 1925 IN ORDER OF MOST DAMAGE
Wheat	16.9	8.9	Bunt, stem rust, loose smut, scab.
Rye	2.32	1.4	Ergot, smut, stem rust.
Barley	11.2	3.78	Covered smut, stripe, loose smut, stem rust.
Oats	8.6	4.8	Smuts, stem rust, crown rust.
Corn	10.7	6.0	Ear rots, root rots, smut, leaf rust.
Potato	21.7	16.2	Late blight, tipburn, mosaic, rhizoctonia.
Sweet potato..	36.2	7.5	Storage rots, stem rot, black rot.
Cotton	19.5	9.1	Angular leaf spot, wilt, root knot, anthracnose.
Dry beans ...	16.1	3.7	Bacterial blight, mosaic, root rots, anthracnose.

Plant diseases may be divided into two groups, (1) those that are parasitic, due to the attack of some organism and (2) non-parasitic diseases, those that are not caused by an organism. Non-parasitic diseases may be the result of unfavorable environmental conditions or to an infectious "virus" which can be transmitted from plant to plant.

948. Important Field Crop Diseases. Parasitic diseases are the more numerous and more definite information is available concerning them. In the following summary the more important diseases attacking crop plants are considered. General diseases are given first and then those attacking only one or a limited number of plants, Table *948a.*

FIELD PRACTICES IN PLANT DISEASE CONTROL.

Some of the means of control suggested in the above summary and of agronomic interest are given more fully in the following paragraphs. The study of the organism itself and its physiological effect are more in the field of plant pathology and identifications of uncommon diseases and their treatment require the services of a pathologist.

949. Resistant Varieties and Strains. Varieties and strains of a variety may differ widely in their susceptibility to disease. Plant

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[1] Office of Mycology and Disease Survey. "Crop Losses from Plant Diseases in the United States in 1925." *The Plant Disease Reporter Supplement 49.* Bureau of Plant Industry. U. S. Dept. Agr. 1926.

948a. Forty of the more important diseases affecting crop plants.[2]

DISEASE AND ORGANISM	CROPS AFFECTED	SYMPTOMS	CONTROL
Mosaic (*visis*)	Tobacco, beans	Dark green and yellow mottling of leaves.	Clean seedbed. Insect control.
	Clover, cowpea	Curled and deformed.	Selection of seed in potatoes.
	Soybean, beet, potato, corn, peanut	Curled and deformed.	
Root Knot (*Heterodera radicicola mematode*)	Cowpea	Root galls found on roots, plants dwarfed.	Rotation with crops not susceptible.
	Soybean	Inside knot is pearly, white body size of a mustard seed.	Use Res. Var.—Iron, Brabham cowpea, Laredo soybean.
	Cotton		Cotton; Res. Var. and Rotations.
	Tobacco		Tobacco; Res. Var.
	Potato		Potato, crop rotation.
Anthracnose (*Colletòtrichum tripolii*)	Clover	Stems and leaves wilt; brown lesions on stems and petioles, spots or lesions.	Use resistant strains.
(*Colletetrichum gossypii*)	Cotton, soybean, beet, burr clover, cowpea, bean	Infected areas appear red, then turn black, then pink, may kill seedling or cause "damping off." Affects leaves, bolls and stems.	Use 2-yr.-old disease free seed—crop rotations. Iron and Brabham cowpeas resistant. Robust bean resistant.
Smut (*Ustilago zeae*)	Corn	Grayish white galls on any part of plant, filled with mass of black spores at maturity.	Crop rotation helps.
Covered smut (*Ustilago hordea*)	Barley	Smutted heads at harvest time, kernels displaced by mass of black spores in membrane.	Seed treatment.
Loose smut (*Ustilago avenae*)			
Covered smut (*Ustilago laevis*)	Oats	As for barley.	Seed treatment.
Bunt or stinking smut (*Tilletia laevis* or *tritica*)	Wheat	As for barley.	Copper carbonate 2 oz. per bu. Res. Var.
Loose smut (*U. Nuda*)	Barley	Smutted heads at flowering time; naked stem of rachis at harvest.	Hot water treatment.

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[2] Compiled from current pathological publications.

948a. Forty of the more important diseases affecting crop plants.—(Continued)

Disease and Organism	Crops Affected	Symptoms	Control
Loose smut (*U. tritici*)	Wheat	As for loose smut of barley.	Seed plot rogued or hot water.
Head smut (*Soro sporium reilianum*)	Sorgo	Head replaced with mass of spores.	Rotation
Kernel smut (*Sphacelothici sorgi*)	Sorghums	Kernels replaced by smut galls filled with black spores at maturity.	Treat seed with formaldehyde or copper carbonate.
Black stem rust (*Puccinia graminis*)	Wheat, oats, barley, rye	Long brick red pustules or stems and leaf sheaths. Later turn black. Particularly bad on spring wheat.	Eradicate common barberry. For oats use resistant varieties,—Iogold. Spring wheat,—sow early. Winter wheat,—use resistant varieties. Kanred. Seed barley early.
Crown rust (*Puccinia coronata*)	Oats	Bright yellow open pustules, make whole plant yellowish.	Res. var. Sterilis group.
Leaf rust (*Puccinia triticana, simplex dispersa*)	Wheat, barley, rye	Yellowish brown pustules, later black on leaves.	Seed barley early. Use resistant var. of wheat,—Kanred.
Rust (*melanpsora lini*)	Flax	Leaves, stems and bolls show bright yellow swellings and masses of spores.	Use resistant varieties.
Fusarium wilt (*F. oxysporum nicotianae*)	Tobacco	Wilting of plant, discolored vascular ring. No ooze on pressing stem.	Avoid infected soils.
Granville wilt (*bacterium solanacearum*)	Tobacco	Plants wilt, vascular ring darkened. Yields ooze on pressure.	Avoid infected soils. Rotation of crops.
Bacterial wilt (*Aplanobacter insidiosum*)	Alfalfa	Plants wilt in hot weather, spindling growth, wood of taproot discolored.	Rotation. Use of hardy and resistant varieties.
Wilt (*fusarium vasenfectum*)	Cowpea Cotton	Leaves become yellow, plants wilt, shed leaves and often die, stems darkened under bark.	Res. var.,—Iron, Brabham cowpea. Res. var.,—Dixie, Dixie Triumph, Lewis 63, Tricook, De Soto, Dix-afifi.
Flax wilt (*Fusarium linii*)	Flax	Wilting of plant, may spread to entire field.	Use Resistant Variety N. D. 114.
(various organisms)	Potato	As for cowpea.	Clean seed. Rotate crop.

DISEASE AND ORGANISM	CROPS AFFECTED	SYMPTOMS	CONTROL
Scab (*Gibberella saubinettii*)	Wheat Rye Barley Corn	Attacks seedlings with light brown rot. Blights spikelets, pink growth on head. Kernels grayish, white to pink, shrunken and light weight.	Do not follow corn with wheat. Fan and treat seed with .6 per cent solution organic mercury compound.
Root, stalk, and ear rots (*Diplodia zeae*)	Corn	Kills seedlings, weakens plants, weak root system, internal discoloration at nodes. Mold on ear. Velvety white mold on germination.	Select seed free of disease, test and discard infected seed. Treat seed with mercury compounds, rotate crops.
(*Giberella saubinettii*)	Corn	As for diplodia except mold on germinator is pink or red.	As for diplodia.
(*Basissporium gallarum*)	Corn	Ears with shredded shank, cob blackened at kernel tips. Kernel tips show black on germinator.	As for diplodia.
Black chaff (*Bacterium translucens undulosum*)	Wheat	Dark streaks on glumes and upper stem.	Use disease free seed.
Stripe (*Helmuthosporium gramineum*)	Barley	Yellowish brown stripes on all but first leaves, plants die and crinkle down.	Treat seed.
Ergot (*Claviceps purpurea*)	Rye, wheat Barley Many grasses	Purplish black, hard bodies develop in place of kernel, bodies are longer than kernels and extend out from chaff.	Use ergot free seed. Rotate crops.
Black fire (*Bacterium angulatum*)	Tobacco	Angular leaf spot, usually with halo, dried area in center, almost black.	Seed-bed sanitation. Use healthy seedlings.
Wildfire (*Bacterium tobacum*)	Tobacco	Round leaf spot surrounded by light ring, halo, yellowish spot.	As for blackfire.
Black root rot (*Thielevia biasicola*)	Tobacco	Stunted plant, blackened scanty root system.	Disinfect seed-bed. Use resistant strains.
Powdery mildew (*Erysiphe polygoni*)	Red clover Alfalfa-Peas	White, powdery mold growing over leaves, leaves wilt somewhat.	Cut first crop early. May help.
Violet root rot (*Rhizoctonia crocorum*)	Alfalfa	Leaves and stems turn yellow and die, roots rotted and covered with violet mycelium.	Rotation.

948a. Forty of the more important diseases affecting crop plants.—(Continued)

Disease and Organism	Crops Affected	Symptoms	Control
Leaf spot (*Pseudopeziza medicaginis*)	Alfalfa	Gray or brown spots on leaves, yellowing of leaves and defoliation.	Cut crop early.
Leaf spot (*Cercospora beticola*)	Sugar beet	First shows small white spot, turns light brown, margin tinged reddish or purple, leaves fall.	Deep fall plowing and crop rotation.
Scab (*Actinomyces scabies*)	Potato	Irregular corky blotches on the surface of tubers.	Treat with formaldehyde or mercury bichloride, use rotation; avoid lime, ashes and fresh manure.
Dry rot (*Fusarium trichothecioides* and others)	Potato	Dry rot at surface extends into potato	Do not bruise potato. Store with low temperature. Ventilate.
Late blight (*Phytophthora infestans*)	Potato	Irregular water soaked areas on foliage, kills entire plant.	Spray with Bordeaux 4-4-50, with high pressure.
Early blight (*Alternarea solani*)	Potato	Spots with rings around them on leaves, shallow decayed areas on tubers.	Spray with Bordeaux 4-4-50.
Black scarf (*Corticum vagum*)	Potato	Plants stunted, leaves curled and rosette, stem rots, girdles stem; causes black spots or reddish spots on tubers.	Treat seed with formaldehyde or mercuric chloride, rotate crops.
Black leg (*Bacillus phytophthorus*)	Potato	Stems turn inky black above ground, leaves yellow and die, tubers discolored at stem end.	Rogue out infected plants. Select and treat seed.
Stem rot (*Fusarium batatatis*)	Sweet potato	Plants become stunted, leaves yellow, plant wilts and dies; stems black inside, black ring in potato.	Select disease free seed. Disinfect seed with mercuric chloride.
Bacterial blight (*Bacterium sp.*)	Soybean	Angular, translucent, later yellow to reddish brown spots. Blackens and kills stem.	Crop rotation, clean seed.
Bacterium malvaceanum	Cotton	As for soybeans, on bolls, often rots entire boll.	As for soybeans.
Bacterium phaseoli	Beans, peas	As for soybeans.	Use western grown seed.
Stem rot (*Sclerotium rolfsii*)	Soybean	Plants gradually wilt and die and stems decay, mycelium occur on surface of soil at base of plant.	No control known, liming of soil recommended.

breeders and pathologists have been coöperating in searching out and developing resistant strains of plants. Resistance to wilt in certain strains of flax, cotton, cowpeas, and other crops are good examples of resistant varieties. Markton is an oat practically immune to covered smut. Many other resistant types have been discovered and continued work offers much promise from this means of combating diseases. It is possible that many so-called resistant varieties may be found susceptible to other forms of the causal organism as it is known that there are distinct physiologic forms of many of the disease organisms.

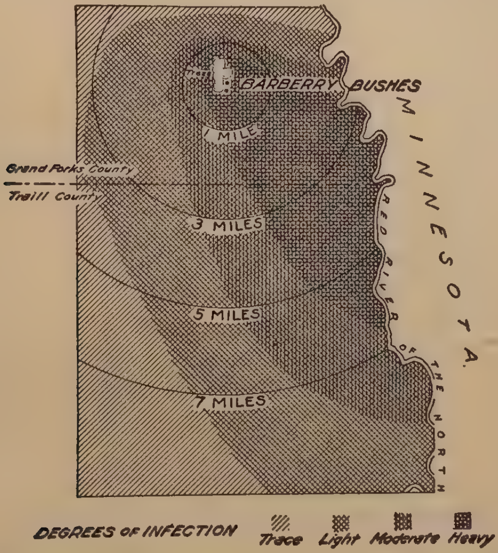

FIG. 159.—Stem rust spreads from the common barberry to grains and grasses. The degree of infection and miles of spread from two bushes found in Grand Forks County, North Dakota, in 1928 is shown.

950. Eradication of Host Plants. The eradication of bushes of the common barberry in the control of the black stem rust of wheat and of the buckthorn in the control of crown rust of oats are examples of disease control through the eradication of host plants. Alternate hosts have been found in a number of diseases of plants and the eradication of these may offer a feasible means for the control of these diseases.

951. Soil Treatment in the Control of Disease. Certain disease-producing organisms live in the soil and soil treatments are possible which aid in reducing the loss from these. Sulfur is sometimes used at the rate of 300 to 600 pounds per acre in the control of potato scab. Heating the soil in tobacco seedbeds in the spring of the year sometime before the seed is sown, by steam or by dry heat, is a rather common practice to control seedling diseases and kill weed seed.

952. Rotation of Crops. Many fungi and other organisms which are the cause of plant diseases attack only certain plants and soon die out in the soil if other crops are planted on the land. The large number of times crop rotation is mentioned as a means of plant disease control in Table *948a,* indicates the importance of this method.

The length of time the disease organisms will live over in the soil in the absence of the crop it attacks has not been determined for many diseases. Soil infection for most diseases is a minor factor after a two-year period in which crops not susceptible to the disease organism are grown. The scab of potatoes and wilt of cotton and of other plants are known to live more than two years in the soil.

Reynolds and Killough[3] determined the percentage of cotton killed by root rot under different cropping systems. They found as an eight-year average that cotton grown continuously had 33.7 per cent of the plants killed, while a three-year rotation of cotton, corn, and oats reduced this loss to 6.7 per cent.

953. Destruction of Plant Residues. Many diseases are carried over from season to season on the waste crop residue, as stalks, straw, and stubble. The covering of such material by deep plowing, or its destruction by burning, is advocated in cases of infestation with certain diseases.

954. Eradication as a Means of Control. The complete removal and destruction of diseased plants from fields, particularly in the case of those diseases where the trouble is commonly carried from one plant to another, is sometimes necessary in disease control. Many diseases of crop plants have alternate wild hosts on which the disease may carry over during a portion of its life cycle.

955. Clean Seed. The use of seed free of disease is also a very important control measure. The use of disease-free seed is in many cases the most feasible method of controlling disease. It is advocated particularly in the control of the rots of corn in which germination tests and observation of the ear and stalk are advocated; also the treatment of seed corn before planting and the treatment of small grain for smut and other seed-borne diseases.

956. Treating Seed Corn. Treating seed corn for the control of seed-borne diseases has been tried extensively, various mercuric and copper compounds being used in liquid and dust forms. Considerable improvement in the compounds sold has been made and no doubt these will continue to be modified as our knowledge of their effect increases.

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[3] Reynolds, E. B., and Killough, D. T.—"Crop Rotation in the Blackland Regions of Central Texas." *Tex. Agr. Expt. Sta. Bul. 365*, p. 10. 1927.

Melhus *et al.*[4] have reported that dry rots cause an average loss of 5 bushels per acre in Iowa. Farmers' "planter box corn" when treated with "Bayer Dust," "Semesan, Jr." or "Merko" gave increases in yield varying from 2½ to 5 bushels per acre. The largest increases were obtained on early planted corn and it was found that treated seed did not rot so quickly in a cold, wet soil as untreated seed. Two ounces of the dust are recommended per bushel of corn with each kernel thoroughly coated with the dust. A barrel churn revolved slowly is suggested as a means of applying the dust.

Holbert *et al.*[5] have reported results in central Illinois to be similar to those of Melhus above.

Kiesselbach[6] found that under Nebraska conditions the organic mercury disinfectants including Uspulum, Semesan, and Bayer Dust, applied to ordinary seed corn, had no significant effect upon the germination, field stand, rate of growth, percentage of smut, lodging, yield per acre, or quality of the product. There was no sign of damage caused by seed-borne diseases to corn grown from either treated or untreated seed under the conditions of these experiments.

957. Small Grain Smut. There are two common kinds of smut that attack small grains: loose smut and covered smut. The spores of the loose smuts are spread at flowering time and become lodged in healthy flowers, infecting the developing seed. In wheat and barley the disease is carried over in the seed itself; it cannot be satisfactorily killed by the seed treatments which affect only the surface of the seed. The hot water treatment known as the modified hot water method for loose smut of wheat and barley as given in *Farmers' Bul. 507*, United States Department of Agriculture, is rather cumbersome for farm use. The method generally advocated for the control of this disease is the use of clean seed obtained either by use of a rogued seed plot or purchase of seed.

The covered smuts of wheat, barley, and oats, and the loose smut of oats may be controlled by external treatment of the seed.

Lambert *et al.*[7] summarize the results from different treatments in 1922, '23, and '24 in 11 states. The object of the test was to determine the effectiveness of the copper carbonate dust treatment as compared with the standard formaldehyde treatment in smut control and the effect of the various treatments on the seed. Nickel carbonate dust, copper sulphate plus lime dust, Semesan dust, and solutions of Upsulum and Semesan were included.

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[4] Melhus, I. E., *et al.*—"Seed Treatments for Corn Diseases." *Ia. Agr. Expt. Sta. Circ. 108.* 1928.

[5] Holbert, J. R., *et al.*—"Chemical Dust Seed Treatments for Dent Corn." *U. S. Dept. Agr. Cir. 34.* Feb., 1928.

[6] Kiesselbach, T. A.—"Experiments with Seed Corn Treatments and Crop Stimulants." *Nebr. Agr. Expt. Sta. Bul. 218.* 1927.

[7] Lambert, E. B., *et al.*—"The Effectiveness of Various Fungicides in Controlling the Covered Smuts of Small Grains." *Phytopathology.* Vol. XVI, No. 6. 1926.

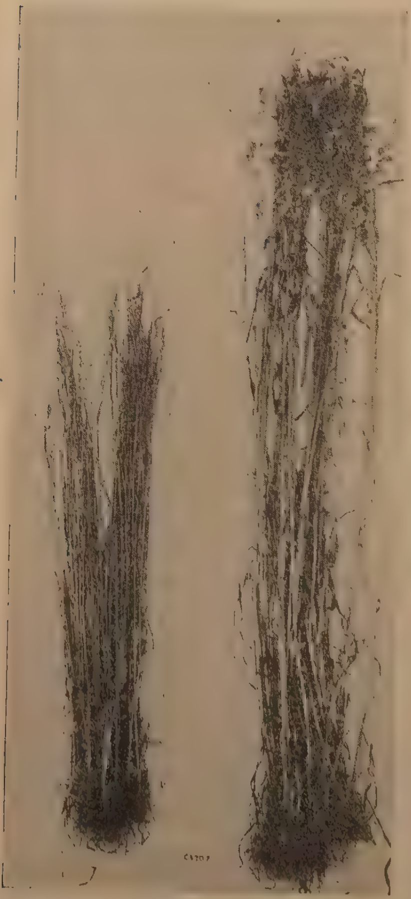

FIG. 160.—Loose smut was responsible for the condition of the oat plants shown at the left. *What is the most practical means of controlling oat smut? Is there more than one kind of oat smut? If so, is the same treatment effective for all?*

Copper carbonate dust was the most satisfactory of the materials for controlling bunt of wheat and smuts of hulless oats. It did not injure the seed appreciably, but practically eliminated the smuts and seemed to have a tendency to increase yields. Formaldehyde controlled the smuts more completely than any of the other materials but often seemed to injure the seed, being especially injurious to hulless oats.

In the copper carbonate dust treatment the procedure usually recommended is to put 2 ounces of the dust per bushel of grain into a tight container and rotate slowly until the grain is thoroughly coated with the dust. Care must be used in order that the dust may not be inhaled by the operator.

Seed wheat treated with copper carbonate dust is not injured by the fungicide even when held in storage for an indefinite period. This permits the treating of seed during the slack season, thus avoiding loss of valuable time during seeding operations. Germination of seed wheat is not inhibited by copper carbonate dust.

Formaldehyde has long been used (1 pint to 40 gallons of water) as a soaking method in treating oat smut and covered smut of barley. From work at the Iowa [8] and at the Illinois stations the use of 1 pint of formaldehyde in 10 gallons of water to treat 40 to 80 bushels of oats is recommended. The oats are shoveled over while the liquid is sprinkled on and will absorb this amount of the solution without showing any degree of wetness or swelling. Still another method recommended considers the use of 1 pint of formaldehyde with 1 pint of water, applied to 40 bushels of oats with an atomizer. Covering the oats for a few hours after treatment is often recommended.

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[8] Hughes, H. D.—"Improved Method of Fighting Smut in Oats." *Iowa Agr. Expt. Sta. Circ. 45.* 1918.

FIG. 161.—Using one pint of formaldehyde in 10 gallons of water to treat 80 bushels of oats. *Does the more expensive dust treatment for smut in oats give returns and possess advantages which justify its use?*

Work has been under way at a number of the experiment stations in an attempt to secure a satisfactory dust treatment for oats and barley. Dusts are now available which will control oat smut and covered smut of barley and barley stripe. The dusts are more costly than formaldehyde but have the advantage of being available to use at any time in advance of seeding.

The Illinois[9] Station reports that in 1928 the use of Ceresan dust increased the yield of the Sixty-Day oat from 64.3 bushels per acre to 78.1 bushels, while the yield of the Big Four oat was increased from 67.6 to 86.7 bushels per acre. This treatment gave perfect smut control but the increase in yield is greater than can be accounted for by smut control alone. Dust treatments for small grain diseases will need to be studied through a period of years before their real economic value can be determined.

958. Potato Scab. The formaldehyde treatment has been so modified[10] as to make it unnecessary to practice the long soaking treatment heretofore necessary in the control of potato scab. The potatoes are merely dipped for two minutes in a hot formaldehyde solution and allowed to dry. Formaldehyde is more active hot than cold. It penetrates faster and kills more rapidly. The solution consists of 2 pints of formaldehyde (40 per cent solution) and 30 gallons of water. This is held at a temperature of 118 to 122° F.

After treatment the potatoes are piled 6 to 8 inches deep and covered with wet sacks for 60 minutes before drying.

[9] Koehler, Benjamin—"New Seed Treatment for Oats and Barley." *University of Illinois. Special Ex. Circ.* Dec. 1928.

[10] Melhus, I. E., and Gilman, J. C.—"An Improved Method of Potato Seed Treatment." *Iowa Agr. Expt. Sta. Cir.* 57. 1919.

This formaldehyde solution, at 122° F., does not injure or delay germination. However, the recommendations as outlined must be followed. The solution should not be allowed to get warmer than 122° F. nor should the potatoes be immersed when the temperature is below 118° F. Too hot a solution will injure or delay germination of the tubers; too cold a solution will not control the diseases.

STUDY QUESTIONS ON CHAPTER XXXIX

1. List the crop plant diseases which are common to your section, with the crops each attacks.
2. List the different methods of controlling plant diseases and give an example of each.
3. Classify the diseases of your section according to the method of control.

APPLICATION ASSIGNMENTS ON CHAPTER XXXIX

1. In your potato patch are many weak plants with curled and mottled leaves? What causes this? What can you do?
2. Many of your corn plants have large, grayish-white balls on the leaves or stalks? What causes this? What can you do?
3. Many of your barley plants have black masses which largely replace the heads. What causes this? What is the remedy?
4. Your spring wheat plants have on the leaves and stems many brick red spots which later turn black. What is the trouble? What is the remedy?
5. Scattered plants in your alfalfa field appear to be dwarfed and weakened. As the season advances many of these wither and die. What is the trouble? What is the remedy?
6. In the germination test of your corn many of the kernels were covered with a velvety white mold? What is the trouble? What is the remedy?
7. In a field of rye many of the kernels are replaced with an elongated, purplish black body. What is it? What precautions should you take?
8. You are not certain of the freedom of your corn from rot diseases. Will you treat your seed? Why? How?

CHAPTER XL

ROTATION OF CROPS

In any section newly brought under cultivation there is a tendency for farmers to grow one crop largely to the exclusion of all others. This crop is the one which is adapted to transportation facilities, climatic conditions, or other peculiarities of the section. It is usually the highest value crop that can be grown extensively and its growth continues until the profitableness of the crop is less pronounced, perhaps because of low yields. In some sections fertility depletion or the disturbed balance of plant nutrients is the factor influencing the change; diseases and insects also are common factors. Weeds, soil erosion, and physical conditions may also make a change of crops desirable. An example of this change is the cycle of flax, wheat and corn, and their general cropping in sections of the corn belt in which each crop has had its turn as the major crop grown. **(72)**

Weitz[1] reports that both on soils used for centuries and on relatively new soils, the annual average yields of the different crops does not show a gradual decline as many would suppose but rather a gradual increase. He also states that while virgin soils rapidly decline in yielding ability for a time they soon reach a stationary state at a rather low yield level and that then with the use of better cultural methods, the rotation of crops, the use of crop wastes, manures and commercial fertilizers, the average yields are gradually increased.

The need of a change from the one-crop system was formerly supposed to be due to waste products thrown off into the soil by the roots of growing plants. **(112)** **(114)** These waste products were supposedly injurious only to the crop by which they were produced, so that a change of crop was necessary in order to avoid the harmful effects of this "sewage." While the benefits which result from a rotation of crops have been definitely shown by many experiments, continued through a series of years, the theory of crop wastes is no longer generally held.

959. Effect of Rotation on Crop Yields. The Illinois Station has reported the annual yields in bushels per acre of corn grown continuously on the same soil through a thirty-eight-year period; also the yield when grown in a two-year rotation with oats and in a three-year rotation with oats and clover. The yields in Table *959a* have been computed from annual reports.

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[1] Weitz, B. O.—"An Analysis of Crop Yield Statistics with Reference to Soil Deterioration." *Jour. Amer. Soc. Agron.* Vol. 18, No. 2, pp. 105-106. Feb. 1928.

959a. Yield of corn grown continuously, in rotation with oats and with oats and clover. Illinois.

Av. of Years	Corn Every Year	Two Years		Three Years		
		Corn	Oats	Corn	Oats	Clover
1888 to 1903 16 years	39.7	41.0	44.0	48.0	47.6	2.03 T.
1915 to 1926 12 years	24.0	34.0	33.0	43.0	55.0	1.9 T.

The Missouri Station[2] reports yields of wheat and of corn grown continuously on the same soils for 29 and for 31 years, respectively, also comparable yields of these crops in rotation in Table *959b*.

959b. Yield of corn and of wheat grown continuously on the same soil and in rotation. Missouri.

Rotation	Corn Yield 31st Year Bu. per Acre	Wheat Yield 29th Year Bu. per Acre
Continuous culture	19.6	0.2
Continuous culture, manured	39.1	10.9
Corn, oats, wheat, clover rotation, ...	52.5	30.0
Corn, oats, wheat, clover rotation, manured	60.1	39.4

The Ohio Station reports the average yield of wheat and of corn through a 20-year period, also yields when grown in rotation.

959c. Yields of wheat and of oats when grown continuously and in rotation. Ohio.

Crop and Rotation	Yield 1st 10 Years	Yield 2nd 10 Years	Av. Yield 20 Years
Corn continuously	21.5	9.43	15.47
Corn in 3-year rotation	36.99	32.87	34.93
Wheat continuously	9.24	5.79	7.52
Wheat in 3-year rotation	9.22	12.78	11.35

On the Broadbalk field at Rothamsted, England,[3] wheat grown continuously for a period of 67 years produces an average yield of

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[2] Hudelson, R. R., and Helm, C. A.—"Crop Rotations for Missouri Soils." *Mo. Agr. Expt. Sta. Bul. 183.* 1921.

[3] Fisher, R. A.—"Studies in Crop Variation." *Jour. Agr. Sci.* Vol. 11, part 2, p. 110. Apr. 1921.

12.2 bushels per acre, while wheat grown continuously and manured produces 34.5 bushels per acre.

Funchess[4] describes an experiment at the Alabama Station in which two plots were continuously cropped to corn and two others to cotton, each plot receiving 160 pounds per acre of acid phosphate and of kainit annually. On one of each of the two plots a legume was seeded between the rows at the last cultivation, while the other plot had no legume. The average yields are shown in Table *959d*.

959d. Average yields of corn and of cotton with and without legume catch crops. Alabama.

TREATMENT	CORN		COTTON	
	Plot 1	Plot 2	Plot 1	Plot 2
	Cowpeas	No Legume	Vetch	No Legume
Yield, first 10 years	19.2 bu.	17.1 bu.	813 lbs.	803 lbs.
Yield, second 10 years	16.2 "	10.2 "	678 "	573 "
Yield, 25th to 29th years	17.3 "	8.5 "	645 "	340 "

Illinois data[5] show the value of rotations of varying lengths and the effect of one, two, and three years of corn in the rotation. Yields in Table *959e* are for the 12-year period, 1914-1925.

959e. Yields of corn in bushels per acre when grown continuously and in rotation. Illinois.

MORROW PLOTS, URBANA	NO SOIL TREATMENT	MANURE, LIME, PHOSPHORUS
Continuous corn	24.6	42.5
Corn, oats (sweet clover catch crop)...	33.8	63.9
Corn, oats, clover	42.8	59.8

SOUTH FARM, URBANA	CROP RESIDUES			MANURE		
	1st Year	2nd Year	3rd Year	1st Year	2nd Year	3rd Year
Wheat, corn, oats, clover	58.0	...	...	63.1	...	...
Corn, corn, oats, clover	53.8	47.4	...	59.5	53.7	...
Corn, corn, corn, soybeans ...	47.0	42.3	39.9	52.4	47.4	41.1

ODIN FIELD	CROP RESIDUES, LIME, BONE PHOSPHATE
Three-year sweet clover rotation: corn, soybeans, wheat (sweet clover catch crop)	26.0
Four-year sweet clover rotation: corn, soybeans, wheat, sweet clover	29.8

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[4] Funchess, M. J.—"The Utilization of Legumes in the Rotation." *Jour. Amer. Soc. Agron.* Vol. 17, No. 7, p. 400, July, 1925.

[5] Bauer, F. C., and Snider, H. J.—"Crop Rotation Tests." *Ill. Agr. Expt. Sta. Ann. Rpt. 39*, p. 9. 1925-26.

In Table *959f* Arny[6] reports the average yield of corn at the Minnesota station when grown continuously on the same land through a 10-year period and when grown in rotation.

959f. Effect of barnyard manure and leguminous crops on the average yield of corn at University Farm, 1905-1914 inclusive. Minnesota.

LENGTH OF ROTATION	CROPS INCLUDED	MEANS OF SUPPLYING VEGETABLE MATTER	YIELD OF CORN PER ACRE BUSHELS
Five years	Grain, clover and timothy hay, pasture, corn, grain	1. Growing clover. 2. Pasturing on hay crops. 3. Applying 8 tons manure per acre preceding corn.	62.45
Three years	Grain, clover, corn	1. Growing clover, hay removed.	42.75
No rotation	Corn each year	1. None.	29.84

Seven rotations have been compared for a period of 10 years in Indiana.[7]

959g. Yields of crops in rotation. Indiana.

ROTATION[a]	AV. CROP YIELDS, 1916-1925				HAY POUNDS	AVERAGE ANNUAL VALUE OF CROPS	AVERAGE ANNUAL COST OF FERTILIZER
	1st Corn Bushels	2nd Corn Bushels	Wheat or Oats Bushels	Soybeans Bushels			
C.O.Cl.	58.8	...	44.6	...	3,197	$25.71	$1.43
C.W.Cl.	51.3	...	24.8	...	3,638	30.70	1.43
C.C.W.Cl.	56.1	48.1	23.1	...	3,426	31.11	1.35
C.S.W.Cl.	60.6	...	36.0	21.2	3,545	34.23	1.07
C.C.S.W.Cl. ..	61.2	55.2	31.8	21.8	3,551	35.55	1.08
C.W.A.	59.2	...	24.5	...	5,151	35.95	1.43
C.C.W.A.A.A. .	64.4	57.1	32.1	...	20,516	46.05	2.07

[a] C, corn; O, oats; Cl, clover; W, wheat; S, Soybean; A, Alfalfa.

960. Effect of Crop Rotations on the Soil. A study in Ohio[8] shows the effect of rotations on the organic matter content and soil nitrogen, as compared with the continuous culture of corn, oats, and wheat. The land was limed and drained, but received no fertilizer treatment.

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[6] Arny, A. C.—"More and Better Acres of Corn for Minnesota." *Minn. Univ. Agr. Ext. Bul. 57.* 1915.

[7] Christie, G. I.—"Comparative Value of Crop Rotat ions." *Ind. Agr. Expt. Sta. Ann. Rpt. 39,* p. 42. 1925-26.

[8] Williams, C. G.—"Forty-fifth Annual Report of the Ohio Agricultural Experiment Station for the Year Ended June 30, 1926." *Expt. Sta. Bul. 402,* p. 20. 1927.

960a. Soil nitrogen and organic matter content as influenced by rotation. Ohio.

CROPPING SYSTEM	YEARS	LBS. PER ACRE IN SURFACE SOIL	
		Organic Matter [a]	Nitrogen
Corn continuous	32	12,516	820
Oats continuous	32	21,722	1,300
Wheat continuous	32	21,826	1,320
Corn, oats, wheat, clover, timothy rotation	32	26,515	1,540
Corn, wheat, clover, rotation	29	29,549	1,760
Original soil (approximate)		36,825	2,240

[a] Organic carbon × 1.724.

Baldwin *et al.*[9] report a comparison of various rotation systems on the nitrifying power of the soil. They found that rotations were effective in producing a high nitrifying power in the following order: (1) Corn, wheat, clover, and timothy. (2) Corn, oats, wheat, clover, and timothy. (3) Corn and wheat. (4) Corn, oats, and wheat, and (5) continuous cultures of either wheat or corn.

Weir[10] made a study of the results of rotation experiments in various parts of the United States and at Rothamsted, England. He finds that the effects of fertilizers and of crop rotations when both are used, each add to the effectiveness of the other and that the highest yields are possible only when both are used. Liming acid soils increased the relative effectiveness of crop rotation.

Wiggans[11] found that good crop rotations without manure were practically as effective in maintaining the production of oats and wheat as were heavy applications of complete fertilizer on crops grown in continuous culture, while the best rotation without manure was practically as good as a heavy application of fertilizer combined with a medium application of manure on crops grown continuously.

961. Crop Sequence. Several stations have observed that the differences in available plant food following the growing of different crops were not sufficient, alone, to account for the differences in yield of succeeding crops.

Thatcher[12] states that there is as yet no positive proof of the nature of the causative agent or agencies for either the beneficial or the injurious effect of one crop upon another. It may vary widely in different cases, and may be either chemical or bacterial in character. Proof that toxic chemical substances in the soil, produced by or in association with the first crop, were the cause of reduced yields has not yet been established.

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[9] Baldwin, J. L., *et al.*—"Nitrate Studies on Purdue Rotation Field No. 6." *Indiana Acad. Sci. Proc. 39*, pp. 269-280. 1923.

[10] Weir, Wilbert W.—"A Study of the Value of Crop Rotation in Relation to Soil Productivity." *U. S. Dept. Agr. Dept. Bul. 1377*, p. 67. 1926.

[11] Wiggans, R. G.—"Experiments in Crop Rotation and Fertilization." *N. Y. [Cornell] Agr. Expt. Sta. Bul. 434*, p. 51. 1924.

[12] Thatcher, R. W.—"The Effect of One Crop on Another." *Jour. Amer. Soc. Agron.* Vol. 15, No. 8, p. 337. Aug., 1923.

Ohio[13] reports the effect of the previous crop on wheat yields over an 11-year period as follows:

PREVIOUS CROP	NO. OF CROPS AVERAGED	YIELD OF WHEAT BUSHELS
Soybeans	66	33.33
Corn	124	34.31
Oats	33	37.34
Clover	33	39.11
Potatoes	62	39.65

Trowbridge[14] reports the effect of crop sequence on wheat yields on manured land in North Dakota.

961a. Effect of the immediately preceding crop on the yield of wheat; six-year average. North Dakota.

PREVIOUS CROP	AV. YIELD PER ACRE OF WHEAT IN BUSHELS	ROTATION
Wheat	16.2	Continuous wheat since 1882
Red clover	24.6	Red clover, wheat, corn, barley
Field peas	21.7	Field peas, wheat, corn, barley
Winter rye	19.4	Winter rye, wheat, red clover, corn
Barley	21.3	Barley, wheat, red clover, corn
Oats	21.9	Oats, wheat, red clover, flax, proso, mangels, or sugar beets
Flax	21.0	Flax, wheat, corn, wheat, barley, millet
Millet	17.3	Millet, wheat, corn, barley
Corn	23.4	Corn, wheat, barley, millet, flax, wheat
Corn	23.0	Corn, wheat, red clover, oats
Corn	26.0	Corn, wheat, red clover, flax
Potatoes	24.1	Potatoes, wheat, red clover, barley

Welton *et al.*[15] report a study of wheat following potatoes. Experimental evidence confirms the impression that wheat following potatoes gives larger yields than following other crops, but there are many years in which this does not hold true.

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[13] Williams, C. G.—"Forty-fifth Annual Report of the Ohio Agricultural Experiment Station for the Year Ended June 30, 1926." *Ohio Agr. Expt. Sta. Bul. 402*, p. 28. 1927.

[14] Trowbridge, P. F.—"Experiment Station Progress." *N. Dak. Agr. Expt. Sta. Bul. 194*, p. 11. 1926.

[15] Welton, F. A., and Morris, V. H.—"Yields of Wheat Following Potatoes and Relation of Nitrates in Soil to These." *Jour. Am. Soc. Agron.* Vol. 16, No. 8, p. 533. 1924.

At the end of many seasons, the nitrate content of potato ground is much higher than is that of corn, oats, wheat, clover, or soybean ground. The high nitrate content of potato ground may be due in part to the small amount of nitrate used by the potato and to the fallow resulting from the early removal of the potato crop.

Winter oats following corn yielded 27.1 bushels, and following cotton 29.3 bushels as a 6-year average in Georgia.[16]

A very extensive study of the influence of particular crops on the crops which follow has been continued through a series of years at the Rhode Island station.[17]

Studies bearing on the causes of the results secured are contained in *Rhode Island Bulletins 198*[18] and *210*.[19]

962. Length of Its Rotation. The question of how frequently a particular crop can be included in a rotation and give maximum production cannot be answered definitely.

In Missouri[20] a 6-year rotation gave an average yield of 41.5 bushels of corn per acre; a 4-year rotation, 38.5 bushels, and a 3-year rotation 32.6 bushels. The average annual value per acre of the crops produced in the 6-year rotation was $14.48; for the 4-year rotation, $17.82, and for the 3-year rotation, $14.18, while a 2-year rotation of wheat and clover had an average acre value of $16.07. Corn was added to this 2-year rotation to make the 3-year rotation, and corn, oats, wheat, and clover was the 4-year rotation, while timothy seeded with clover and left 2 additional years made the 6-year rotation.

In many cases the returns from rotations of varying lengths are not directly comparable, as the rotations are carried out on separate pieces of land which may vary in fertility. Stevenson *et al.*[21] report a series of rotations on the Wisconsin drift soil in which the total value of crops per acre for a 10-year period, on a 5-year rotation, was $278.58, a 4-year rotation $339.33, a 3-year, $246.21; a 2-year, $227.02, and continuous corn, $240.50. The crop included in the different rotations has an inportant bearing on the value of the crops produced in any period of years.

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[16] Stanton, T. R., Childs, R. R., Taylor, J. W., and Coffman, F. A.—"Experiments with Fall Sown Oats in the South." *U. S. Dept. Agr. Dept. Bul. 1481*. 1927.

[17] Hartwell, Burt L., and Damon, S. C.—"The Influence of Crop Plants on Those Which Follow. I." *R. I. Agr. Expt. Sta. Bul. 175*. 1918.

[18] Burgess, Paul S.—"The Yield and Mineral Content of Crop Plants as Influenced by Those Preceding." *R. I. Agr. Expt. Sta. Bul. 198*. 1924.

[19] Hartwell, Burt L., Smith, John B., and Damon, S. C.—"The Influence of Crop Plants on Those Which Follow. III." *R. I. Agr. Expt. Sta. Bul. 210*. 1927.

[20] Miller, M. F., and Hudelson, R. R.—"Thirty Years of Field Experiments with Crop Rotation, Manure, and Fertilizers." *Mo. Agr. Expt. Sta. Bul. 182*. 1921.

[21] Stevenson, W. H., Brown, P. E., and Forman, L. W.—"Crop Returns under Various Rotations in the Wisconsin Drift Soil Area." *Iowa Agr. Expt. Sta. Bul. 241*, p. 255. 1926.

963. The Value of Various Kinds of Crops in the Rotation. Rotations generally advocated have a cultivated crop or row-crop, a small grain and a sod crop. The value of a legume as the sod crop has been indicated in data on green manures. Under certain conditions and for particular crops a grass may be as effective as clover in the rotation in maintaining yields. In rotation work in Indiana the yield of wheat in the 18th year was 25.2 bushels in a rotation of corn, oats, wheat, clover (2nd crop clover plowed under); 29.1 bushels where the rotation was corn, oats, wheat, and grass; and 25.6 bushels where the grass was replaced by clover and grass.

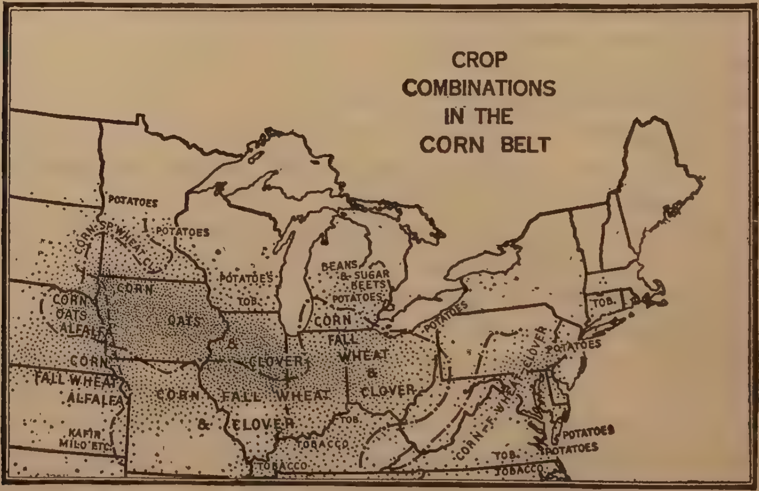
CROP
COMBINATIONS
IN THE
CORN BELT
POTATOES
CORN-SP. WHEAT-CL.
POTATOES
POTATOES
TOB.
BEANS
& SUGAR
BEETS
POTATOES
CORN
CORN
OATS
ALFALFA
OATS
&
CLOVER
CORN
FALL WHEAT
&
CLOVER
POTATOES
TOB.
CORN-F. WHEAT-CLOVER
POTATOES
CORN
FALL WHEAT
ALFALFA
CORN FALL WHEAT
& CLOVER
TOB.
KAFIR
MILO ETC.
TOBACCO
TOBACCO
POTATOES
POTATOES
TOB.
TOBACCO

Fig. 162.—*The dots on the above map indicate the corn acreage while the broken lines divide the regions of crop combinations. Account for the different combinations of crops found in different parts of this area.* (U. S. Dept. Agr. Yearbook 1921, page 176.)

Jordan and Churchill[22] report the yields for a 16-year period of studies in New York in which the influence of clover was compared with timothy in rotation with corn, oats, and wheat. Without the use of fertilizers the yield has been maintained with no decrease in productivity for the last 12 years. No significant difference has been noted in the yield of the grain crops in rotation with timothy as compared with clover.

At the Ohio Station[23] as an average for a 4-year period, plowing under red clover, mammoth clover, and sweet clover in a 2-year rotation of corn, oats, and legume catch crops, resulted in increases of

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[22] Jordan, W. H., and Churchill, G. W.—"An Experience in Crop Production." *N. Y. Agr. Expt. Sta. [Geneva] Bul. 465*, p. 13, 1919.

[23] "Sweet Clover as a Green Manure Crop." Forty-ninth Annual Report. *Ohio Agr. Expt. Sta. Bul. 402*, p. 18. 1926.

1.6, 3.9, and 9.0 bushels of oats per acre, respectively, and 7.8, 7.5, and 18.1 bushels of corn when considered in comparison with the yields of a corn and oats rotation without the catch crop.

Wiggans[24] studied rotations including various combinations of wheat, oats, grass, clover, and potatoes. Continuous culture, alternate grains and 3-year rotations were used. He states that without doubt clover is more valuable than timothy in a rotation under the conditions of the experiment.

In a comparison of the yield of oats in a rotation of (a) oats, wheat, and grass, (b) oats, wheat, and potatoes (cultivated crop), and (c) oats, wheat, and clover, the oats, wheat, grass rotation gave yields 21.6 per cent lower and the oats, wheat, clover rotation 3.1 per cent lower than the oats, wheat, potatoes rotation. The oats, wheat, grass rotation produced 20.4 per cent lower average yields of oats than an oats, grass, potatoes rotation.

An interesting experiment in Ohio[25] is being carried out where a rotation of (1) corn, (2) potatoes, (3) wheat, and (4) clover is compared with the same crops arranged (1) potatoes, (2) corn, (3) wheat, and (4) clover. In another rotation the order of planting wheat and clover is reversed. The crop sequence is indicated in Table *963a* by the numbers in parentheses.

963a. The effect of changing the order of crops in a rotation. Yields average, in bushels or tons, for a ten-year period. Ohio.

ROTATION	CORN	POTATOES	WHEAT	CLOVER
First rotation	(1) 72.27	(2) 103.12	(3) 35.26	(4) 1.95
Second rotation	(2) 58.54	(1) 146.75	(3) 34.63	(4) 1.87
	CORN	OATS	WHEAT	CLOVER
First rotation	(1) 65.11	(2) 65.88	(3) 35.09	(4) 1.92
Second rotation[a]	(1) 69.15	(2) 59.68	(4) 38.65	(3) 1.84

[a] In this rotation a catch crop of sweet clover is used in the wheat and plowed down for corn.

As an 8-year average, using prevailing prices, the rotation potatoes, corn, wheat, and clover returned $7.07 per acre more annually than the corn, potatoes, wheat, and clover rotation in spite of the lower yields secured from all the crops but the potatoes.

The effect of Sudan, oats, and soybeans on the yield of corn when grown in a two-year rotation with corn has been reported from the Iowa station.[26] No manure or fertilizers were used and all crop prod-

[24] Wiggans, R. G.—"Experiments in Crop Rotations and Fertilization." *N. Y. Agr. Expt. Sta. [Cornell] Bul. 434.* 1924.

[25] "Forty-third Annual Report." *Ohio Agr. Expt. Sta. Bul. 382*, p. 21. 1924.

[26] Hughes, H. D., and Wilkins, F. S.—"Sudan Grass." *Iowa Agr. Expt. Sta. Bul. 233.* 1927

ucts were removed except the corn stalks, which were plowed under. The yields given in Table *963b* are average for seven crops.

963b. Yield of corn in bushels per acre when grown in rotation with oats, Sudan grass and soybeans. Iowa.

ROTATION	AIR-DRY YIELD	STAND; STALKS PER HILL	PER CENT OF MOISTURE IN THE CORN AT HARVEST
Corn and Sudan grass	59.7	3.74	34.7
Corn and oats	56.4	3.78	38.7
Corn and soybeans	57.9	3.90	31.2

964. Labor. In arranging a rotation of crops the distribution of labor must have consideration. Two crops which compete directly for labor must be so regulated in acreage that both can be cared for. This usually necessitates the growing of row-crops in combination with small grains and hay. Labor-saving devices which make possible the efficient use of labor at harvest time, as in wheat harvest, tend somewhat to reduce the necessity of limiting the acreage, when considered from the standpoint of labor requirements and labor distribution.

Another consideration of importance is the preparation of the seedbed for the succeeding crop. The growing of a certain crop may make the preparation of the seedbed for the succeeding crop less difficult, as when wheat can follow corn cut for silage, soybeans, or other crops without plowing.

965. Flexible Rotations. Some farmers have a major crop rotation in which their chief cash value crop and soil building crops occur regularly, so that their enterprises may be planned in advance. But the crops used to fill in between these need not be determined so long ahead and the manager can take advantage of temporary periods of under production or high prices for particular crops, such as soybeans, flax, or new varieties of a crop which promise a high profit at the time, though not normally a high profit crop if grown regularly or continuously. A flexible rotation of this type enables a farmer to vary the acreage of some of the minor crops and take advantage of opportunities for higher profits in a given year.

966. Control of Pests. One of the more important functions of crop rotation is the control of insects, diseases, and weeds. Insects and diseases which live on one particular crop can increase more rapidly under continuous culture of the crop than where the crops are moved about from one field to another. In the same way it may be impossible to control the increase of certain weeds on certain crops in the rotation while the normal cultivation at the time of plowing for some other crop almost automatically results in their destruction.

967. Erosion and Rotations. In planning a crop rotation the lay of the land and the need of guarding against destructive erosion may be very important. Continued cultivation of row-crops has rendered some rolling farms practically worthless for immediate crop production. In the past, considerable acreages of sod land have been plowed and used for a time in growing row-crops profitably, only later to be abandoned due to excessive erosion. As has been shown, the danger of erosion varies with the type of crop grown. **(207) (208) (209)**

STUDY QUESTIONS ON CHAPTER XL

1. List the different reasons for rotating crops. In most cropping systems when is the rotating of crops usually begun? Explain.
2. Why should the sequence of crops on the land have any effect on the net total return from the crops grown through a period of years? Explain.
3. What governs the usual length of a rotation for a section? Explain.
4. List the things a good rotation must provide.
5. Illustrate the ways in which the labor factor influences rotations.
6. Indicate the ways in which the soil fertility and topography influence rotations.
7. What prediction would you make with reference to the future use of commercial fertilizers in crop production?

APPLICATION ASSIGNMENTS ON CHAPTER XL

1 Select an imaginary farm in your section and give the cropping history of this land from the beginning of its cultivation to the present, together with the reasons for the changes.

2. You have a farm of average fertility and want to devise a cropping system which, in so far as possible, will maintain the producing power of the land. List the considerations that will determine what will be necessary.
3. Outline a practical system of cropping and supplementary treatments that will maintain the producing power of your land.
4. Why is there so much variation in the wheat, cotton and corn belts with reference to the need and type of rotations used?

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